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The Application of Work Domain Analysis to Defining Australia's Air Combat Capability

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Joint and Operations Analysis Division
Defence Science and Technology Organisation

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ABSTRACT

The Royal Australian Air Force's Air Combat Capability is currently undergoing a significant restructure as new, advanced platforms are introduced to the fleet. To avoid a loss of capability in the air domain, the Royal Australian Air Force must determine how best to employ its current and future fighter jets to meet operational goals. To support this objective, this report presents a comprehensive work domain analysis—or structural description—of Australia's Air Combat Capability, defined across multiple levels of abstraction and decomposition, and independent of specific platforms. This analysis has already demonstrated its usefulness in contributing to the development of an Australian air power doctrine and strategy narrative, represented in the next edition of the Royal Australian Air Force's Air Power Manual (AAP 1000-D). Future applications of this model could contribute to capability requirements definition; air combat force structure development and organisational redesign; air combat specific crewing concepts, training programs, and Concept of Operations; and the continued development of military doctrine and strategy.

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Executive Summary

Australia's Air Combat Capability is a pivotal component of the Australian Defence Force. In recent years the combat fleet of the Royal Australian Air Force has undergone a major shift in force structure, with new platforms and capabilities being introduced. To manage this rapid change, the Royal Australian Air Force must continually evaluate Australia's Air Combat Capability against an evolving and dynamic military environment.

In support of this objective, this report presents a comprehensive work domain analysis of Australia's Air Combat Capability. Work domain analysis, the first phase of cognitive work analysis (Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999), results in a detailed structural description of a system. This framework has demonstrated its efficacy in a variety of contexts and across a number of different focus systems. In applying work domain analysis to Australia's Air Combat Capability, capabilities are defined across multiple levels of abstraction and decomposition, and independent of specific platforms like Hornet, Super Hornet, or Joint Strike Fighter. As a result, this report provides a detailed understanding of the functional purposes, values and priorities, functions, and physical resources of Australia's Air Combat Capability as independent of current or future air combat platforms. Importantly, this approach allows capabilities to encapsulate a range of scenarios and situations, thus enhancing the breadth and usefulness of the analysis.

The work domain model of Australia's Air Combat Capability has already established its utility by contributing to the philosophical content and conceptual framework of a narrative of Australian air power doctrine and strategy, published as the Royal Australian Air Force's Air Power Manual (AAP 1000-D). Specifically, the model was used as a basis for refining how pivotal air power concepts, such as purposes, goals, values, functions, missions, and roles, are defined, characterised, and interrelated (Brady, Naikar, & Treadwell, 2013; Naikar, Treadwell, & Brady, 2014). Future applications of this analysis could include capability requirements definition, air combat force structure development, and the organisational design of the Royal Australian Air Force. Additionally, this model has the potential to support the development of crewing concepts, training programs, and Concept of Operations explicitly tailored to the work demands of Australia's Air Combat Capability.

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1. Introduction

This report presents a comprehensive work domain analysis of Australia's Air Combat Capability. The principal product of this analysis is a structural description—or model—of the Air Combat Capability in terms of five levels of abstraction. Specifically, it describes the purposes the Air Combat Capability must fulfil, the values and priorities it must be capable of preserving or satisfying, the functions it must be capable of performing, and the physical devices or resources the Air Combat Capability must have in order to fulfil its functions, values and priorities, and purposes.

This package of work has been undertaken for the Support for Future Air and Space Capabilities task (AIR07/036), sponsored by Air Force Headquarters. Under this task, the work domain model described in this report has contributed to the development of an Australian air power doctrine and strategy narrative, represented in the next edition of the Royal Australian Air Force's Air Power Manual (AAP 1000-D) (Brady, Naikar & Treadwell, 2013; Naikar, Treadwell & Brady, 2014). The potential future applications of the model include capability requirements definition, force structure development, and the organisational redesign of the Royal Australian Air Force. In addition, the model could be used to support the construction of air combat specific crewing concepts, training programs, and Concept of Operations, and in refining and shaping future Air Force doctrine and strategy.

Prior to presenting the work domain model, this report will outline contemporary issues for Australia's Air Combat Capability and provide a background to work domain analysis, a formative modelling technique (Vicente, 1999). Additionally, the methodology used to construct Australia's Air Combat Capability work domain model will be described, with the results of this work domain analysis comprehensively presented. Finally, this report will discuss the limitations of this analysis, and describe the extensions of this work in the future.

1.1 Background

The Royal Australian Air Force is currently undergoing a major shift in its force structure (Borgu, 2004; Davies, 2010, 2011). This shift is particularly apparent within the air combat sphere, where new platforms, and consequently capabilities, are being introduced. From both a strategic and financial perspective, the Royal Australia Air Force must consider how best to manage these changes so that it retains its defence posture in the Asia-Pacific region.

Australia's air combat history is extensive. Since the Royal Australian Air Force's formation in 1921 (Royal Australian Air Force, 2008b), aircraft have played a pivotal role in the protection of Australia and its citizens. Over the years, combat aircraft have supported multiple military operations (e.g., Operation Slipper, Operation Falconer; Royal Australian Air Force, 2012a), provided regional security support (e.g., Operation Acolyte; Royal Australian Air Force, 2012a), and been utilised in numerous interservice and multinational

training exercises (e.g., Exercise Red Flag; Department of Defence, 2013a). However, in recent years, Australia's air combat force has commenced a transitioning process, shifting away from role-based, third-generation fighters, to a more integrative, multi-functioning, future-orientated (i.e., stealth, advanced avionics) force (Air Power Development Centre, 2012; Davies, 2010). This transition commenced with the decommissioning of the Aardvark aircraft (F-111) in late 2010 and the upgrading of the classic Hornet fleet (F/A-18A/B) to ensure its use into the next decade (Borgu, 2004; Quaife, 2007). Combined with the acquisition of the Super Hornet platform (F/A-18F) and Growler capability (EA-18G), as well as the highly publicised future purchase of the fifth-generation Joint Strike Fighter (F-35) (Borgu, 2004; Davies, 2011), Australia's air combat force is markedly different from that of a decade ago.

In light of the substantial changes occurring within Australia's air combat sphere, the Australian Defence Force and the Royal Australian Air Force must take appropriate measures to avoid a loss of capability within its air domain. This is particularly important given the key role Australia's air combat platforms play in maintaining and sustaining Australia's strategic objectives. As outlined in the recently released Defence White Paper (Department of Defence, 2013b), Australia's core national security interest is the protection of Australia and its citizens against direct armed attack. To achieve this end, the Australian Defence Force must be capable of defending Australia's air and sea approaches, ensuring the security and stability of Australia's immediate region, and upholding its commitment to international alliances and treaties. In support of these outcomes, the Royal Australian Air Force must be capable of effectively utilising different combinations of air combat platforms to comply with specific operational requirements and identifying suitable upgrade options and candidates for future acquisition. These decisions, if made appropriately, have the potential to further support the defence of Australia into the 2030-2050 timeframe, whilst enhancing overall cost effectiveness. A work domain analysis can contribute to achieving these outcomes by providing a comprehensive structural description of Australia's Air Combat Capability.

1.2 Work domain analysis

There are many benefits to a structural description, or work domain model, of a system. In the first instance, within a work domain analysis framework, a system's purposes are linked explicitly to its physical devices by a number of hierarchical levels representing the system at multiple levels of abstraction and decomposition. The comprehensive nature of this modelling technique allows for multiple types of information to be integrated, ultimately providing an extensive blueprint of an entire system. This blueprint can, in turn, support the identification of a system's capabilities as inclusive of its purposes through to its physical resources.

A further benefit of work domain analysis centres upon its capacity to account for unanticipated events or situations (Naikar, 2013; Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999). In particular, work domain analysis focuses on analysing the inherent constraints (or capabilities) in a system, rather than the specific tasks or procedures required of a system, making it event and actor-independent. By adopting this approach,

no matter what situation or scenario an air combat aircraft is in, the capabilities defined within a work domain model remain the same. This issue is of principal importance when analysing future-based systems, like Australia's air combat fleet in 2030, as the military environment or the manner in which air combat platforms are utilised in twenty years time is uncertain. Therefore, by mapping out the constraints of a system, the applicability of the model is considerably broadened.

A final benefit of work domain analysis relates to the research undertaken by Naikar (2006, 2009, 2013), Naikar and Sanderson (1999, 2001), and Naikar, Pearce, Drumm, and Sanderson (2003). This work formally recognises the value of work domain analysis in defining technological and organisational requirements of two diverse military systems, specifically the Airborne Early Warning and Control platform (Naikar et al., 2003; Naikar & Sanderson, 2001) and the classic Hornet platform (Naikar & Sanderson, 1999). The work domain models they produced were used to inform the development of tender evaluation schemes, team design, and training needs analysis, as specifically tailored to the work demands of those individual platforms (Naikar, 2006, 2009, 2013). The success of these work programs indicate that the work domain analysis framework is useful for broadly defining capabilities for military systems when applied to such problems.

Based on the evidence summarised above, work domain analysis could be used to define capabilities for future-based, dynamic systems. In support of this proposition, the current report will present a work domain analysis of Australia's Air Combat Capability. This analysis aims to define the Air Combat Capability generically, or independently of specific air combat platforms like Hornet, Super Hornet, or Joint Strike Fighter. By defining capabilities in this manner, the useability of Australia's Air Combat Capability work domain model is broadened to support a variety of applications. This approach differs from the research undertaken by Naikar and Sanderson (1999) which demonstrated the value of work domain analysis in modelling a single air combat aircraft, the classic Hornet. Though the iteration of the model presented within this report only includes current technologies (i.e., that which is currently known to be fitted to a classic Hornet, Super Hornet, or Joint Strike Fighter), this work domain model provides a framework whereby prospective air combat capabilities could be represented as well.

1.3 Modelling approach

Work domain analysis is the first phase of cognitive work analysis (Rasmussen et al., 1994; Vicente, 1999). Cognitive work analysis, developed by Rasmussen et al. and subsequently extended by Vicente, is a formative modelling technique used to analyse work in complex sociotechnical systems. It is a constraint-based framework, consisting of five phases of analysis which focus on identifying different types of constraints within a system. This technique has been applied across a variety of domains, extending to industrial (e.g., Rasmussen, Pejtersen, & Schmidt, 1990), medical (e.g., Hajdukiewicz, Vicente, Doyle, Milgram, & Burns, 2001; Watson & Sanderson, 2007), aviation (Ahlstrom, 2005; Borst, Suijkerbuijk, Mulder, & van Paassen, 2006), and military sectors (e.g., Bissantz, Roth, Brickman, Gosbee, Hettinger, & McKinney, 2003; Burns, Bryant, & Chalmers, 2005; Jenkins, Stanton, Walker, Salmon, & Young, 2008; Naikar et al., 2003; Naikar & Sanderson,

1999, 2001; Torenvliet, Jamieson, & Chow, 2008). The work by Naikar and her colleagues, in particular, has demonstrated the wide-ranging, positive contribution cognitive work analysis can make to future-orientated military systems (Naikar, 2006, 2009, 2013).

Work domain analysis is an event and actor-independent framework used to represent and identify the functional structure of a system (Rasmussen et al., 1994; Vicente, 1999). It primarily consists of five levels of abstraction - the purposes, values and priorities, functions, processes, and physical devices of a system. The main product of this technique is an abstraction hierarchy, which represents those five levels in schematic form. As depicted in Figure 1, the functional purpose sits at the highest point of the abstraction hierarchy, with the individual, physical devices represented along the lowest level. As described by Naikar (2013), the functional purpose level of abstraction describes the objectives of a system and the external constraints on its operation. This level captures the fundamental reasons for which a system exists, and the services or outputs that a system is responsible for delivering. The value and priority level of abstraction, the second highest level of abstraction, depicts the criteria that must be respected for a system to attain its functional purpose. Criteria can be characterised as fundamental laws, principles, or values. The third abstraction level, the purpose-related function, represents those functions a system must be capable of affording for the system to achieve its higher level objectives. The bottom two levels of abstraction depict the physical properties of the system. In particular, the object-related processes are the functional processes, capabilities, or limitations of the physical objects, and the physical objects level depicts the system's material devices.

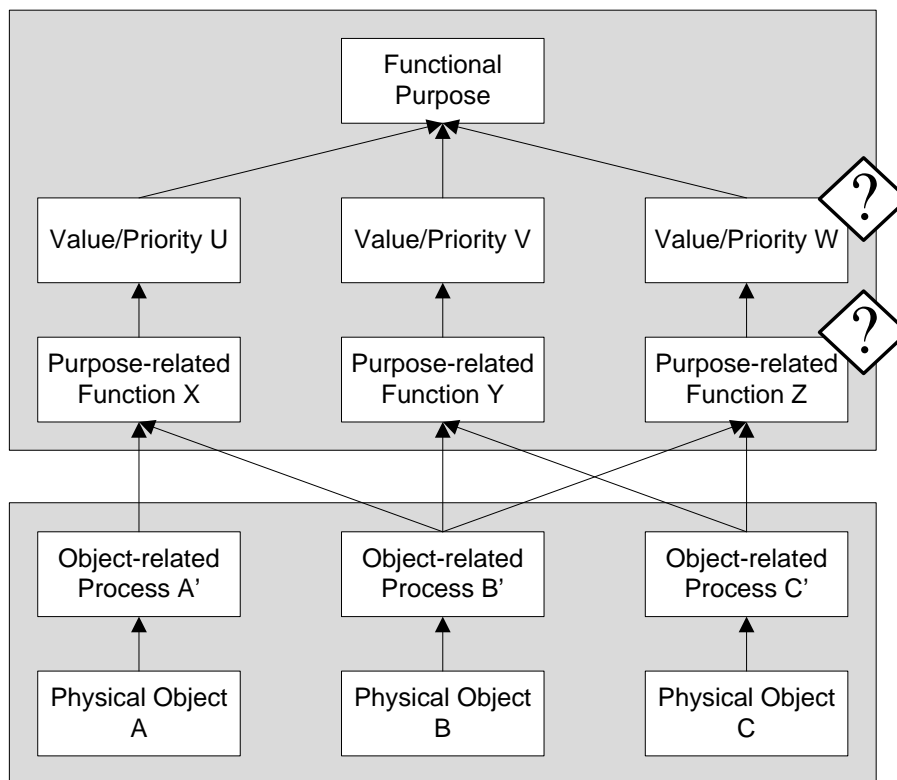


Figure 1 A generic abstraction hierarchy (Reproduced from Naikar, 2013)

As shown in Figure 1, multiple nodes, or categories of constraints, are represented across the five levels of abstraction. Each node is either connected to one or multiple nodes at adjacent abstraction levels, typically referred to as structural means-ends relations. Specifically, nodes represented at lower levels of abstraction depict the structural *means* of a system, whilst higher levels of abstraction represent the structural *ends*. As illustrated in Figure 1, *Physical Object A* is the means to how *Object-related Process A'* is achieved, with *Purpose-related Function X* specifying the ends to why *Object-related Process A'* is represented in the focus system.

As the work domain analysis framework is event and actor-independent, the categories of constraints represented within a work domain model are relatively stable across time and space. Therefore, regardless of what scenario or situation the analysed system is in, the identified purposes, values and priorities, functions, and physical resources remain the same – these constraints do not change from situation to situation. By utilising this framework, both novel and unanticipated events are captured, thus enhancing the survivability of the system being analysed.

2. Methods

The methodology utilised for developing the work domain analysis of Australia's Air Combat Capability comprises eight analytic themes (Naikar, 2013). These themes are: what is the purpose of the analysis; what are the project restrictions; what are the boundaries of the analysis; is it useful to develop multiple models; where on the causal-intentional continuum does the focus system fall; what are the sources of information for the analysis; what is the content of the abstraction-decomposition space; and is the abstraction-decomposition space a valid model of the focus system. The primary aim of these themes is to support analysts in defining the scope and content of a work domain model. As specific to the current report, only five themes will be discussed in depth, as they are regarded as the most pertinent for the purposes of this report. A comprehensive examination of all the themes in the application to this model will be presented in another paper.

2.1 Purpose of the analysis

The first theme of the work domain analysis methodology concerns establishing the purpose of the analysis. This is a pivotal step in the development of a work domain model as the purpose or intention of the analysis can have significant implications for the final representation of the model.

To determine the purpose of the analysis two considerations must be made. Firstly, what is the objective of the analysis, and secondly, how will a work domain model be used to achieve that aim. For the current analysis, the research objective was to define Australia's

current and future Air Combat Capability, independently of specific platforms, such as Hornet, Super Hornet, or Joint Strike Fighter. To achieve this aim, a work domain model would represent the Air Combat Capability in terms of five levels of abstraction.

2.2 Boundaries of the analysis

The third theme involves marking out the system, or aspects of the system, that are to be the focus of the analysis. This decision can be approached from several angles, namely, the organisational entity, physical entity, problem, and actors' perspective.

For the current analysis, the organisational entity that was the focus of the analysis was the Royal Australian Air Force. The physical entity was the air combat aerial system. This analysis purposely omitted ground-based systems, like training facilities or mission planning centres, due to constraints associated with time and personnel. The problem that defined the focus of the analysis was how to most effectively utilise a combination of platforms to fulfil the requirements of Australia's Air Combat Capability now and in the future. The analysis was modelled from the perspective of Air Force Headquarters, the strategic and policy arm of the Royal Australian Air Force (Royal Australian Air Force, 2012b).

2.3 Sources of information

The sixth theme concerns the sources of information for the analysis. Typically, the main information sources for developing a work domain model are documents, field observations, and subject matter experts.

The first iteration of the air combat model, which is presented in this report, primarily employed document analysis. Documents that were consulted and analysed included: Royal Australian Air Force doctrine, such as the Air Power Manual (Royal Australian Air Force, 2008a) and the Future Air and Space Operating Concept (Royal Australian Air Force, 2008c); strategic and policy reports, such as the Defence White Paper (Department of Defence, 2009¹); operating procedures and training manuals for current Australian air combat aircraft; and internal and external websites, which provided the latest information relating to air combat capabilities in the global aviation sphere.

Importantly, the information sourced from these documents was not simply extracted and situated within the air combat work domain model. Work domain analysts are required to search for constraint-based, actor and event-independent data, which is neither readily obvious nor available in texts written for different purposes. In general, documents, field

¹ Although the 2009 edition of the Defence White Paper was used to support the development of the Air Combat Capability model, a work domain analysis describes relatively stable concepts. Accordingly, the specific content of the most recent edition of the Defence White Paper (2013), which was not available during model development, does not invalidate the results presented in this report.

observations, and subject matter experts depict how work *should be done* (normative approach) or *is done* in a system (descriptive approach)², rather than explicitly providing information relating to why work is done a particular way or alternatives to how this work can be done (formative approach)³, the foundational bases of work domain analysis theory (Naikar, 2013).

2.4 Content of the abstraction-decomposition space

The seventh theme focuses on developing the content of the abstraction-decomposition space. Table 1 presents the abstraction-decomposition space developed for Australia's Air Combat system. This representation shows the abstraction-decomposition space is comprised of an abstraction dimension, a decomposition dimension, and categories of constraints (Rasmussen et al., 1994). Specifically, the abstraction dimension, formed along the vertical axis, depicts qualitatively distinct constructs of a system through means-ends relations, with the decomposition dimension, located on the horizontal axis, representing the system at different levels of detail or resolution (Naikar, 2013). The categories of constraints, generically described within the cells of the abstraction-decomposition space in Table 1, depict the functional structure of a system at different levels of abstraction and decomposition.

² Vicente (1999) describes the distinction between normative and descriptive methods of work analysis.

³ Vicente (1999) describes how work *can be done* in a system as a formative approach to work analysis.

Table 1 A skeletal abstraction-decomposition space of the Air Combat system

	Aerial system	Subsystems	Components
Functional Purposes	<i>Functional purposes of the aerial system</i>	<i>Functional purposes of the subsystems</i>	<i>Functional purposes of the components</i>
Value and Priority Measures	<i>Value and priority measures of the aerial system</i>	<i>Value and priority measures of the subsystems</i>	<i>Value and priority measures of the components</i>
Purpose-related Functions	<i>Purpose-related functions of the aerial system</i>	<i>Purpose-related functions of the subsystems</i>	<i>Purpose-related functions of the components</i>
Object-related Processes	<i>Functional capabilities or limitations of the aerial system</i>	<i>Functional capabilities or limitations of the subsystems</i>	<i>Functional capabilities or limitations of the components</i>
Physical Objects	<i>Physical form of the aerial system</i>	<i>Physical form of the subsystems</i>	<i>Physical form of the components</i>

Based on a process of document analysis, the standard five levels of abstraction (Rasmussen, 1986; Rasmussen et al., 1994) were identified as relevant to the Air Combat system: functional purpose, value and priority measures, purpose-related functions, object-related processes, and physical objects (Table 1). These levels are not necessarily applicable to every system (see, for example, Vicente & Wang, 1998); rather, different systems may require different levels of abstraction (Naikar, 2013).

Document analysis also led to the identification of three levels of decomposition as being relevant to the Air Combat system, specifically, the aerial system, subsystems of the aerial system (for example, weapons or sensors), and components of those subsystems (for example, air-to-air missiles or infra-red sensors) (Table 1). These varying levels enable the analyst to view the problem space with more or less detail as required.

Following the identification of the abstraction and decomposition levels, selected cells of the abstraction-decomposition space were populated with constraints to create the abstraction hierarchy of Australia's Air Combat Capability. Specifically, the cells along the diagonal of this matrix were populated with constraints as indicated by the shading in Table 1. (The actual constraints of the model will be presented later in the report.) Though it is theoretically possible to populate all the cells in the abstraction-decomposition space, previous research indicates that the most effective and useful work domain models are developed along the diagonal (Naikar, 2013).

2.5 Validity of the model

The final, eighth theme of the work domain analysis methodology concerns the validity of the model, specifically whether the model provides an accurate and comprehensive representation of the focus system. There are two techniques to validating a work domain model, review with subject matter experts and matching the model to real cases or scenarios. However, ultimately, the model must be evaluated on its usefulness. Usefulness in this context refers to whether the analysis was useful for the purpose for which it was developed.

The Air Combat Capability model has been validated in two ways. First, three highly experienced and knowledgeable Air Force personnel from Air Force Headquarters and the Air Power Development Centre reviewed three levels of the model, specifically the functional purpose, the value and priority measures, and the physical objects. This review resulted in only two changes to the labels of the value and priority measures, and not to the specific content of the model. Second, in terms of the usefulness measure, the air combat analysis has demonstrated its value in contributing to the next edition of the Air Power Manual (AAP 1000-D). Future validation exercises for the Air Combat Capability model will be discussed in the final section of this report.

3. Results

The primary outcome of the work domain analysis of Australia's Air Combat Capability is an abstraction hierarchy. This hierarchy, as outlined in earlier sections of this report, is a schematic representation of five, clearly delineated, levels of abstraction. For the purposes of the current report, the results at each level of abstraction are listed below. A foldout of the entire Air Combat Capability abstraction hierarchy is provided in Appendix A, with further detail available in analyst documentation in appendices B-F.

3.1 Functional purpose

The functional purpose of Australia's Air Combat system is '*To protect Australia from attack by providing the ability to apply lethal force from the air, within a wide radius of sovereign territory, whilst respecting legal and ethical constraints, and minimising risk to the aircraft and its crew*'. The primary terms used in this statement, which are underlined, are defined and described in Appendix B.

3.2 Value and priority measures

A set of five value and priority measures were identified for the Air Combat system. The values and priorities are represented in Table 2. Additional detail, including specific measures and further definitions of the underlined terms, is provided in Appendix C.

Table 2 The Air Combat system's values and priorities at the aerial system level of decomposition

Values and priorities	Definitions
Impedability	The ability of the Air Combat system to <u>render</u> a specified <u>target</u> <u>ineffective</u> .
Knowledge	The ability of the Air Combat system to <u>obtain</u> <u>information</u> about a <u>target</u> , whilst simultaneously <u>exploiting</u> this information and <u>denying</u> the adversary's ability to do the same.
Safety	The ability of the Air Combat system to <u>preserve</u> <u>human</u> and <u>material resources</u> concentrated within the Air Combat system and those <u>friendly forces</u> with which the Air Combat system interacts with.
Humanity	The ability of the Air Combat system to <u>preserve</u> the <u>civilian population</u> and its <u>infrastructure</u> .
Resource efficiency	The ability to <u>conserve</u> the <u>use</u> of <u>expendable material resources</u> concentrated within the Air Combat system.

3.3 Purpose-related functions

Six purpose-related functions were found to be applicable for the Air Combat system. As shown in Table 3, each function has an accompanying definition, with its primary terms underlined. Analyst documentation (Appendix D) provides supplementary detail regarding each purpose-related function.

Table 3 *The Air Combat system's purpose-related functions at the subsystem level of decomposition*

Purpose-related functions	Definitions
Destruction	The ability of the Air Combat system to <u>destroy</u> a specified <u>entity</u> beyond <u>functionality</u> or <u>restoration</u> .
Disablement	The ability of the Air Combat system to <u>disable</u> a specified <u>entity</u> from <u>achieving</u> its <u>goals</u> for as long as <u>necessary</u> .
Information collection and dissemination	The ability of the Air Combat system to <u>collect</u> and <u>disseminate</u> <u>information</u> related to its environment or a specified <u>entity</u> .
Self protection	The ability of the Air Combat system to <u>protect</u> itself from <u>external dangers</u> .
Piloting	The ability of the Air Combat system to <u>move</u> as <u>directed</u> , through the <u>air</u> and on the <u>ground</u> , in relation to a <u>preferred route</u> .
Survival assistance	The ability of the Air Combat system to <u>sustain</u> the <u>life</u> of its <u>aircrew</u> in <u>adverse situations</u> .

3.4 Object-related processes

A total of fifty-three object-related processes were identified for the Air Combat system, specifically nine at the subsystem level of decomposition, and forty-four at the component level of decomposition (Table 4). Analyst documentation in the form of a glossary (Appendix E) defines each object-related process in considerable detail.

Table 4 *The Air Combat system's object-related processes at the subsystem and component levels of decomposition*

Object-related processes: Subsystem level	Object-related processes: Component level
Flight	Aerodynamic lift
	Directional stability and control
	Thrust
	Weapons, chaff, and flare release
	Electrical power supply
	Fuel storage and supply
	Ground supply and movement
	Hydraulic power supply
	Environmental control

Object-related processes: Subsystem level cont'd	Object-related processes: Component level cont'd
System management	Flight control
	Mission computing
	Information display
	Flight management
Localisation	Position, velocity, and time information
	Position, orientation, and velocity calculation
	Altitude calculation
	Distance and bearing calculation
	Precision approach
Information transmission	Long distance, voice transmission
	Medium distance, voice transmission
	Short distance, voice transmission
	BLOS ⁴ digital data transmission
	LOS ⁵ digital and imagery data, and voice transmission
	Enhanced BLOS ⁶ digital data transmission
	Internal voice data
	Imagery data
	Emergency signalling data
Sensing	Range, azimuth, and elevation information
	Size and shape information
	Identity information
	Presence and bearing information
	Presence, size, shape, azimuth, and elevation information
Threat warning	Missile threat warning
	Laser threat warning
	RF ⁷ threat warning
Detonation	Air-to-air collision
	Air-to-surface collision
	Laser-guided homing collision
	Ballistic trajectory collision
	Close air collision
Threat deception	Infra-red jamming
	Electronic jamming
Life support	Crew sustainment
	Ejection

3.5 Physical objects

The Air Combat system consists of nine physical objects at the subsystem level of decomposition, and forty-four physical objects at the component level of decomposition (Table 5). Each physical object is comprehensively defined in a glossary (Appendix E).

⁴ Beyond Line-of-Sight

⁵ Line-of-Sight

⁶ Beyond Line-of-Sight

⁷ Radio Frequency

Table 5 The Air Combat system's physical objects at the subsystem and component levels of decomposition

Physical objects: Subsystem level	Physical objects: Component level
Air vehicle	Airframe
	Propulsion system
	Dispenser system
	Power supply system
	Fuel supply system
	Landing gear
	Hydraulic flight system
	Environmental control system
Mission control	Flight control system
	Mission computer
	Workstations
	Flight management system
Navigation	Global positioning system
	Inertial navigation system
	Radar altimeter
	Tactical air navigation
	Precision landing guidance system
Communication	HF ⁸ radio
	VHF ⁹ radio
	UHF ¹⁰ radio
	Link 11
	Link 16
	Link 22
	Inter-communications system
	Common data link
	Radio beacon set
Sensor	Radio detection and ranging
	Infra-red
	Identification friend or foe
	Electronic support measures
	Electro optical
Threat warning	Missile warning receiver
	Laser warning receiver
	Radar warning receiver
Weapon	Air-to-air missile
	Air-to-surface missile
	Laser-guided bomb
	Unguided bomb
	Cannon
Countermeasure	Flare
	Chaff
	Decoy
Survival assistance	Survival stores
	Ejection system

⁸ High Frequency

⁹ Very High Frequency

¹⁰ Ultra High Frequency

4. Discussion

This paper presents a comprehensive work domain model of Australia's Air Combat Capability, as defined across five levels of abstraction. In particular, the model describes the purposes, values and priorities, purpose-related functions, object-related processes, and physical devices required of Australia's contemporary Air Combat Capability. Within this multifaceted model, the Air Combat Capability is defined independently of actors and events. This feature of the air combat work domain analysis leads to a broad understanding of the capability that is needed across a range of situations and scenarios, including those that cannot be predicted or anticipated.

The potential applications of the Air Combat Capability work domain model encompass four areas of research and design: capability requirements definition; military doctrine and strategy; organisational structure and evaluation; and the development of crew concepts, training programs, and Concept of Operations. Though these applications appear diverse, a work domain analysis has the capacity to be applied across multiple problems as it is produced independently of the specific context in which the focus system is used. The succeeding discussion will illustrate how the Air Combat Capability analysis has the potential to be applied across a broad and dynamic problem space.

4.1 Applications of the Air Combat Capability model

4.1.1 Capability requirements definition

At the outset, the air combat work domain model has the potential to support the definition of Australia's Air Combat Capability requirements. Initial research suggests that work domain analysis could complement traditional techniques used to define capability requirements (e.g., systems engineering). The Australian Defence Force presently defines 'capability' as:

"The power to achieve a desired operational effect in a nominated environment within a specified time and to sustain that effect for a designated period"
(Department of Defence, 2012, p. 119).

This definition describes capabilities with reference to particular actions or tasks within specified parameters (i.e., time, space). Though applicable in many circumstances, given that the majority of events a system encounters are known or routine, this definition is limited to the consideration of expected or predictable capabilities. In a similar vein, traditional techniques to capability requirements definition usually adopt normative (what should be done) or descriptive (what is presently done) frameworks (Ernst, Jamieson, & Mylopoulos, 2006; Finkelstein, 1994; Hansen, Berente, & Lyytinen, 2007; Pohl, 2006; Pöppelbuß & Röglinger, 2011), which can result in defining capability requirements within the bounds of current practice or optimal output. Conversely, work domain analysis could provide a different, complementary approach to capability requirements definition by specifying capability requirements as independent of actors or events. This is particularly

important when modelling future systems like Australia's Air Combat system, where future military environments cannot be easily predicted. Therefore, in utilising a work domain analysis framework in concert with more traditional approaches, the identification of Australia's Air Combat Capability requirements may be further strengthened.

4.1.2 Military doctrine and strategy

In terms of military doctrine and strategy, as stated previously, the Air Combat Capability work domain model has been applied to the development of the Royal Australian Air Force's Air Power Manual (AAP 1000-D). Released approximately every five years, this publication describes the fundamental principles guiding air power objectives and the strategic issues associated with air power (Air Power Development Centre, 2010b). The Air Combat Capability analysis assisted the delivery of these end goals by informing the philosophical content of this foundational Australian air power text and by providing a conceptual framework for examining its logic, rigour, and coherence. In particular, the model provided a systematic basis for defining, characterising, and connecting pivotal air power concepts, such as purposes, goals, values, functions, missions, and roles, contributing to a sound statement of doctrine and strategy. A more detailed description of these contributions is discussed in Brady et al. (2013) and Naikar et al. (2014).

The extension of this work in the future will look to support air power doctrine and strategy from the outset of publication development. In particular, the Air Combat Capability analysis has the potential to shape air power principles and objectives, with a particular focus on air combat issues, by refining how doctrine and strategy is formulated and applied, across multiple levels of abstraction and decomposition. In addition, the utility of this model could be expanded to support Joint defence doctrine and strategy, and in defining areas of science and technology air combat support.

4.1.3 Organisational structure and evaluation

A further application of the Air Combat Capability analysis is assisting the Royal Australian Air Force with its force structure development and organisational design. The Royal Australian Air Force is currently undertaking a redesign to its military capability and service delivery (Air Power Development Centre, 2008a, 2008b; Blackburn, 2007). These changes span from planned acquisitions and upgrades to retraining personnel for new roles in future airborne platforms (Air Power Development Centre, 2008a, 2008b; Blackburn, 2007). It is intended that the air combat work domain model will be employed, as part of a larger modelling exercise, to assist the Air Force in developing a flexible and adaptive organisational structure (Naikar, 2012). This work recognises the compelling evidence in the literature that the most effective organisational designs are those that can accommodate and adapt to a range of situations and scenarios, including those that are novel and unanticipated (Rasmussen et al., 1994; Rochlin, La Porte, & Roberts, 1987; Vicente, 1999). As such, no single or best organisational structure will be defined. Rather, emphasis will be placed on identifying the set of possibilities required for work organisation in a system, ultimately redesigning the Royal Australian Air Force with consideration to these possibilities.

4.1.4 Crew concepts, training programs, and Concept of Operations

The final potential application of the air combat work domain analysis concerns the development of crew concepts, training programs, and Concept of Operations explicitly tailored to the work demands of Australia's Air Combat system. This model could be used to identify how best to allocate tasks to operators across the Hornet, Super Hornet, and Joint Strike Fighter platforms, thereby informing crew concepts, to define the skills required by operators in order to achieve their allocated tasks to support training requirements, and to devise new approaches for the construction of Concept of Operations. Although previous work by Naikar and her colleagues has highlighted the utility of work domain analysis for developing crewing concepts and training system requirements for military systems (Naikar and Sanderson, 1999; Naikar et al., 2003), this framework is yet to be applied to the development of Concept of Operations. Primarily employed in the military domain, Concept of Operations describes how to achieve mission objectives in an operational setting (Daniels & Bahill, 2004; Institute of Electrical and Electronics Engineers, 1998, 2011). These types of documents are typically developed informally, with little methodological grounding (Daniels & Bahill, 2004). The Air Combat Capability work domain model can support the construction of these types of documents by providing an event and actor-independent structure for determining how best to employ multiple fighter platforms within a dynamic military environment.

4.2 Future validation techniques

To strengthen the utility of the Air Combat Capability work domain analysis, further validation of the model would be beneficial. Strategies for validation most commonly involve review with subject matter experts and scenario mapping exercises. For the Air Combat Capability analysis, reviews have already taken place with subject matter experts from the Royal Australian Air Force. Additional applications of this validation strategy could look to utilise a different sample cohort to that used previously. Scenario mapping exercises performed by subject matter experts or analysts using real incidents or devised scenarios (Naikar, 2013) could also contribute to establishing the validity of the Air Combat Capability work domain model. Notwithstanding such validation techniques, the ultimate test for the validity of a work domain model is its usefulness. Further applications of the model extending beyond the doctrine and strategy work previously undertaken for Air Force would provide supplementary assessments of the air combat analysis against measures of usefulness.

4.3 Future directions

The future directions of the Air Combat Capability analysis could encompass the development of a second iteration of the model. This may comprise a finer level of detail to that of the current, first iteration presented in this report. Detail in this context refers to the integration of worldwide, future-centric air combat technologies, and superimposing air combat platforms onto the model.

The first iteration of the work domain model of Australia's Air Combat Capability provides a contemporary representation of this system. Specifically, the model represents all subsystems and components fitted to the currently operational classic Hornet and Super Hornet, and to the future Joint Strike Fighter. However, emerging air combat technologies are currently not reflected in this capability model. Within the air combat sphere emerging technologies can include fighter platforms and their subsystems and components currently in development. At present, a number of countries (e.g., China, Russia, Japan) and aircraft manufacturers (e.g., Shenyang Aircraft Corporation, Sukhoi Company, Mitsubishi) are in the process of developing technologically enhanced air combat platforms (Clodfelter, 2009; Laird, 2009). These platforms are expected to be operational over the next decade, and are likely to possess greater stealth, manoeuvrability, avionic systems, and data fusion capacity (Air Power Development Centre, 2010a; Clodfelter, 2009; Laird, 2009) than that seen before in the air combat environment. In an extension of this work, defence technologists and the aviation industry are also theorising and developing initial prototypes of air combat platforms for the post 2030 timeframe, coined as sixth-generation fighters (Tirpak, 2009). These potentially unmanned future systems are expected to utilise advanced electronic and cyber attack capabilities, offer superior speed, reach, and situational awareness, and provide greater levels of self protection (e.g., shape shifting capabilities, self-healing capabilities) (The Economist, 2011; Tirpak, 2009). By including such information within a second iteration of the Air Combat Capability work domain analysis, a more comprehensive and inclusionary representation of air combat capabilities would emerge. Knowledge of such information could have implications for future Royal Australian Air Force air combat acquisitions, and enhance the Australian Defence Forces' awareness of other nations' air combat capabilities.

A further feature of the second iteration of the air combat analysis could look to superimpose air combat platforms onto the work domain model. By layering technical and operative design characteristics of, for example, Australia's classic Hornet, Super Hornet, and Joint Strike Fighter (i.e., speed, weapon trajectory range, altitude level range, load levels), a blueprint of Australia's entire air combat fleet would be evident. The model could then be used to determine appropriate mixes of platforms depending on the situation or scenario, and highlight capability gaps or redundancies in Australia's air combat sphere. Likewise, other air combat platforms could be superimposed onto the Air Combat Capability model, be it alliance-based platforms (i.e., The Australia, New Zealand, United States Security Treaty [ANZUS]; Department of External Affairs, 1997; Rudd, 2010), to support the management of current and future international operations, or prospective air combat upgrades and acquisitions post that of Joint Strike Fighter. In addition, those platforms considered a regional threat to Australia's national security could be superimposed onto the model thereby providing a comparative Air Combat Capability analysis. Though broad, these future directions of the air combat work domain model have the potential to strengthen the utility of the analysis during the application phase of this research.

4.4 Conclusions

This report has presented a comprehensive work domain analysis of Australia's Air Combat Capability. This model defines the Air Combat Capability across multiple levels of abstraction and decomposition, and as independent of actors and events. By contextualising a system's capabilities in this manner, an infinite number of scenarios and situations are accounted for, thus enhancing the usability of the model, and ultimately, the survivability of the focus system. The model of Australia's Air Combat Capability has demonstrated its utility in contributing to the next edition of the Royal Australian Air Force's Air Power Manual (AAP 1000-D), an official statement of Australian air power doctrine and strategy. Future applications of this analysis have the potential to support the Royal Australian Air Force and the Australian Defence Force more broadly in capability requirements definition, force structure development and organisational redesign, military doctrine and strategy definition, and the development of air combat specific crewing concepts, training programs, and Concept of Operations.

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Appendix A: Air Combat Capability Abstraction Hierarchy

This appendix presents the Air Combat Capability abstraction hierarchy. A sample of the structural means-ends links between each node is enclosed as a separate document.

Appendix B: Air Combat Capability Functional Purpose Analyst Documentation

This appendix presents an unclassified version of the analyst document developed for the Air Combat Capability functional purpose. Each primary term of the functional purpose statement is defined, with a rationale and supporting documentation provided.

FUNCTIONAL PURPOSE

Functional Purpose Statement:

To [protect Australia](#) from [attack](#) by [providing](#) the [ability](#) to [apply lethal force](#) from the [air](#), within a [wide radius of sovereign territory](#), whilst respecting legal and ethical constraints, and [minimising risk to the aircraft and its crew](#).

[Protect:](#)

Definition:

- “To defend or guard from attack, invasion; cover or shield from injury or danger” (Macquarie Dictionary Online, 2010).
- “A tactical task to provide safety for an individual, group or force and prevent any loss as a result of enemy or other action” (Department of Defence, 2010).

Rationale and supporting documentation:

- In the context of the current analysis, the term ‘protect’ is used to imply a constant state of preparedness or readiness against potential threats or threat-type situations (attacks/invasions) which could otherwise injure or effect danger. As such, the functional purpose of air combat is not to solely defend Australia and its interests, as documented in Air Force publications, but to maintain a level of preparedness to defend if an attack is operationalised. Therefore, the concepts of ‘defending’ and ‘guarding’ against/from attacks/invasions are encapsulated by use of the word protect.

[Australia:](#)

Definition:

- “The continent South-East of Asia, lying between the Indian and Pacific Oceans” (Macquarie Dictionary Online, 2010).
 - Please note this definition is only useful insofar as it provides a geospatial location for Australia. Specific details regarding [airspace](#) and [maritime boundaries](#) are required so as to inform us of the exact territorial demarcation of Australia.
 - [Australian airspace](#): “Australian territorial airspace is the airspace above any part of Australia, its territories, internal waters and its territorial seas” (Royal Australian Navy, 2000).
 - [Australian maritime boundaries](#): “Under international law, Australia has rights and responsibilities over its adjacent waters, which are divided into maritime zones. The main international agreement outlining these rights and responsibilities is the United Nations Convention on the Law of the Sea, or UNCLOS. UNCLOS defines the following maritime zones: territorial sea; contiguous zone; exclusive economic zone; continental shelf” (Attorney-General’s Department, 2013).

Rationale and supporting documentation:

- The purpose of this analysis is to identify Australia’s Air Combat Capability requirements now and in the future. As demonstrated in the majority of Royal Australian Air Force (RAAF) publications, the principle service of Australia’s Air Force is to secure/protect/defend “Australia’s people, interests and way of life” (Royal Australian Air Force, 2008a, p. 13). Therefore, inclusion of Australia, as both a physical object (i.e., its landmass, airspace, and maritime boundaries) and an inherent value system (i.e., constitutional democracy, freedom of speech and association, rule of law), within the functional purpose statement is required.

Attack:*Definition:*

- “To set upon with force or weapons; begin hostilities against” (Macquarie Dictionary Online, 2010).
- “To take offensive action against a specified objective” (Department of Defence, 2010).
- “An offensive military operation with the aim of overcoming the enemy and destroying their armed forces and will to resist” (Macquarie Dictionary Online, 2010).

Rationale and supporting documentation:

- A primary requirement of air combat (generically) is to attain and maintain the capability to apply lethal force against attacks or potential threats of attack. The current analysis defines attack as an injurious or hostile act against Australia as a physical object or Australian values or national interests.

Provide/providing:*Definition:*

- “To furnish or supply” (Macquarie Dictionary Online, 2010).
- “To afford or yield” (Macquarie Dictionary Online, 2010).

Rationale and supporting documentation:

- The Air Combat system needs to be able to afford a lethal force capability so as to expend such force when protecting Australia from attack or the possibility of attack. The act of providing lethal force implies a constant capability which is maintained and can be attained when required.

Ability:*Definition:*

- “Power or capacity to do or act in any relation” (Macquarie Dictionary Online, 2010).

Rationale and supporting documentation:

- To direct lethal force towards potential or actual attacks (combative threats) the Air Combat system must have the ability/capability to apply such force.

Apply:*Definition:*

- “To bring to bear; put into practical operation as a principle, law, rule, etc.” (Macquarie Dictionary Online, 2010).

Rationale and supporting documentation:

- In order to achieve the functional purpose of air combat (i.e., protect Australia using lethal force), the air combat aircraft must be able to operationalise such lethal force. The use of the word ‘apply’ allows for such lethal force to be realised.

Lethal force:*Definition:*Lethal:

- “Relating to, or such as to cause death” (Macquarie Dictionary Online, 2010).

Force:

- “Strength or power exerted upon an object” (Macquarie Dictionary Online, 2010).

Lethal force:

- “Any action taken which is intended to cause serious bodily injury or death” (Department of Defence, 2010).
- “Physical force which, under the circumstances in which it is used, is readily capable of causing death or serious physical injury” (US Legal.com, 2013).

Rationale and supporting documentation:

- As outlined previously, the primary aim of Australia's Air Combat aerial system is to protect Australia (inclusive of its physical landmass, value systems, and national interests) from attack. In order to adequately ‘protect’ Australia from potential or actual attacks, the capability to apply lethal force through the discharge of weapons is required.
- It is important to highlight that use of the term ‘lethal force’ in the functional purpose statement does not imply that lethal force will always be utilised in the event of an attack. Rather, this statement emphasises that Australia's Air Combat system exists to provide a lethal force capability - regardless of whether this force capability is realised or simply acts as a deterrent against possible attacks.
- Reference to ‘lethal force’ within the current analysis is not dissimilar to the generic definitions outlined above with additional legal and ethical limitations placed upon its usage (these points will be further raised in more detail in the analyst document for value and priority measures).

Air:*Definition:*

- “A mixture of oxygen, nitrogen and other gases, which surrounds the earth and forms its atmosphere” (Macquarie Dictionary Online, 2010).

Rationale and supporting documentation:

- All forms of air combat occur in the air environment, therefore inclusion of the term ‘air’ in the functional purpose level of abstraction is vital for consistency in the analysis.

Wide radius of sovereign territory:*Definition:*Wide:

- “Over an extensive space or region, or far abroad” (Macquarie Dictionary Online, 2010).

Radius:

- “A circular area of an extent indicated by the length of the radius of its circumscribing circle” (Macquarie Dictionary Online, 2010).

Sovereign:

- “One that exercises supreme authority within a limited sphere” (Merriam-Webster Dictionary Online, 2010).

Territory:

- “The land and waters belonging to or under the jurisdiction of a state, sovereign, etc.” (Macquarie Dictionary Online, 2010).

Rationale and supporting documentation:

- Within the context of the current analysis, the phrase ‘wide radius of sovereign territory’ emphasises that Australia's Air Combat Capability exists to protect Australia beyond its immediate shores and territories. By using the term ‘wide radius’, this captures the fact that the Air Combat aerial system needs to have the capability to perform strategic strike outside designated sovereign territory. That is, Australia's Air Combat aerial system needs to be

able to apply lethal force at a potential enemy's centre of gravity¹¹ (e.g., military bases, ground forces) regardless of their location (e.g., air, land, or sea; enemy occupied territory; Australian [sovereign] territory).

Minimising risk to the aircraft and its crew:

Definition:

Minimising:

- "To reduce to the smallest possible amount or degree" (Macquarie Dictionary Online, 2010).

Risk:

- "Exposure to the change of injury or loss; a hazard or dangerous chance" (Macquarie Dictionary Online, 2010).

Aircraft:

- "Any machine supported for flight in the air by buoyancy or by dynamic action of air on its surfaces" (Macquarie Dictionary Online, 2010).

Crew:

- "The persons operating an aircraft in flight" (Macquarie Dictionary Online, 2010).

Rationale and supporting documentation:

- The Air Combat Group, RAAF, and Australian Government aims to reduce casualties and material losses when protecting Australia from attack or attack-like situations (Department of Defence, 2009, p. 66; Royal Australian Air Force, 2008b, p. 36). Therefore, minimal risk to Australian air combat aircraft and its crew members is required for the functional purpose of air combat to be achieved. Additional details regarding this particular statement will be outlined in the analyst documents for value and priority measures.

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¹¹ Centre of gravity: "Characteristics, capabilities or localities from which a nation, an alliance, a military force or other grouping derives its freedom of action, physical strength or will to fight" (Department of Defence, 2010).

Appendix C: Air Combat Capability Value and Priority Measures Analyst Documentation

This appendix presents an unclassified version of the analyst documentation developed for the Air Combat Capability value and priority measures. Each value and priority is defined, with primary and secondary measures outlined, and rationale and supporting documentation provided.

IMPEDABILITY

Definition of Impedability:

'Impedability' is defined as the ability of the Air Combat system to [render](#) a specified [target ineffective](#). Specifically, the Air Combat aerial system must have the capacity to provide both a [lethal](#) and [non-lethal](#) force capability to assist in protecting Australia.

Render:

The act of rendering something is defined as "to make or cause (a person or thing) to be or become as specified" (Macquarie Dictionary Online, 2011). Within the context of air combat impedability, the ability to 'render' denotes the Air Combat systems' capacity to produce an effect which either removes, or significantly degrades, a target's ability to achieve their mission objectives/goals. As such, the term 'render' represents the means through which the outcome, an ineffective target, is achieved. Various [lethal](#) (e.g., kinetic weapons) and [non-lethal](#) (e.g., jamming, distortion) methods can be utilised to affect this outcome, with the damage and duration of impedability dependent on the type of method used.

- [Lethal:](#)

The term 'lethal' is described as "the method of attack which is intended to cause physical damage to personnel, material, or capabilities" (Department of Defence, 2011). This term has been further defined as "capable of causing death" (Collins Dictionary Online, 2011). Based on these definitions, the concept of lethality is fundamentally tied to outcomes relating to physical damage, which inherently infer long-term, permanent injury or harm, impairing an entities value or usefulness (adapted from Macquarie Dictionary Online's definition of 'damage', 2011). Specific to the current analysis, lethal methods encompass the usage of kinetic weaponry (e.g., missiles, bombs) to destroy a target's physical capability to do something (Butler, 2008), as implemented within certain ethical and legal guidelines¹².

- [Non-lethal:](#)

The Department of Defence (2011, adapted from The United States Department of Defense *Policy for Non-Lethal Weapons* [Directive No. 3000.3, 9 July 1996]) defines 'non-lethal weapons' as "explicitly designed and primarily employed so as to incapacitate personnel or material while minimising fatalities, permanent injury to personnel, and undesired damage to property and the environment". By adopting the above definition, the term 'non-lethal', within the current value and priority measure, can be described as impermanent acts of incapacitation against a target, without necessarily causing physical damage¹³.

Target:

The Department of Defence (2011) defines 'target' as "the object of a particular action, for example a geographic area, a complex, an installation, a force, equipment, an individual, a group or a system". Though broad, this definition enables the concept of 'target' to capture an extensive number of physical objects, ranging from personnel, material, or capabilities. Within the context of air combat impedability, the term 'target' will refer primarily to an enemy target¹⁴.

¹² 1949 Geneva Conventions and the subsequent 1977 Additional Protocols (inclusive of Law of Armed Conflict [LOAC]; Conventional Weapons Convention (restrict the use of incendiary weapons and the use of cluster and fragmentation weapons against anyone but combatants); 1992 Chemical Weapons Convention (prohibited to develop, produce, stockpile, test, and use chemical weapons); Treaty of Rarotonga (prevent the stationing of nuclear weapons on Australian sovereign land); principles of Aerial Targeting, Rules of Engagement, LOAC (Pender, 2004, p. 42).

¹³ It is important to highlight that the concept of non-lethal, and that of non-lethal weapons, is differentiated from methods of information warfare, as outlined in the knowledge value and priority measure analyst document. This same view is held by Squadron Leader C. R. Coles, Royal Australian Air Force (2003), who stated "while [information warfare is] regarded as non-kinetic in effect and non-lethal by intent, [such methods] will not be included in the definition of 'non-lethal weapons'".

¹⁴ It is important to recognise that the term 'target' within the context of air combat *knowledge* is used more broadly such that it is not primarily directed at the enemy.

Ineffective:

The term 'ineffective' is defined as "having no effect or an inadequate effect" (Collins Dictionary Online, 2011). As specific to air combat impedability, to render a target, as a total system or its individual subsystems, ineffective is to deny it from achieving its objectives/goals. For example, for the communication system to be effective in any airborne platform (e.g., enemy fighter jet) or ground based centre (e.g., enemy command and control¹⁵ centre) it must have the capacity to exchange and receive information¹⁶. Loss of such capacity would render the communication system ineffective, and therefore incapable of achieving its purposive objectives.

Measures:❖ **Primary measures:**

1. Destruction to a target required = Destruction to a target achieved.
2. Incapacitation of a target required = Incapacitation of a target achieved.
 - The primary measures stated above are criteria that must be respected in order for the Air Combat system to achieve its functional purpose. These measures assume that an air combat aircraft must have the capacity to render a target ineffective through two methods – lethal (acts of destruction) and non-lethal (acts of incapacitation). In providing this capacity, the Air Combat system can protect and, if necessary, defend Australia against attacks.

❖ **Secondary measures:**

1. Accurate delivery of weapons at a target required = Accurate delivery of weapons at a target achieved.
2. Timely delivery of weapons at a target required = Timely delivery of weapons at a target achieved.
3. Efficient delivery of weapons at a target required = Efficient delivery of weapons at a target achieved.
 - At this stage, these measures are purely illustrative examples of secondary measures for air combat impedability. A more comprehensive description of the secondary measures will be developed in the second iteration of this model.

Rationale and supporting documentation:

- ❖ Impedability is a value and priority measure for the Air Combat system. The Air Combat system must be capable of successfully impeding a specified target through lethal or non-lethal means, when required, in order to achieve its functional purpose. Principally, it is this capability which enables the protection of Australia¹⁷ and its friendly forces against current and future attacks:
 - "The fundamental reason for creating any warfighting organisation is to provide the nation with an ability to apply force, sometimes lethal force, in support of its national interests. Our Air Force exists to apply force in and from the air" (Royal Australian Air Force, 2008b, p. 37).

¹⁵ The North Atlantic Treaty Organisation defines a 'command and control system' as "an assembly of equipment, methods and procedures and, if necessary, personnel, that enables commanders and their staffs to exercise command and control" (North Atlantic Treaty Organisation [NATO], 2010).

¹⁶ Refer to the value and priority measure of knowledge for air combat for a thorough definition of 'information'. This definition is readily applicable to any one of the value and priority measures for the Air Combat system.

¹⁷ The term 'Australia' is inclusive of its people (i.e., civilians, Australian Defence Force [ADF] personnel), territories, material and natural resources, air and sea approaches, and its value system (Royal Australian Air Force, 2008b, p. 9).

- “The ADF is the only agency of the Government that is empowered to apply lethal force in such operations to defend Australia’s people, interests and way of life” (Royal Australian Air Force, 2008a, p. 41).
- ❖ To better understand the specific contribution air combat affords to impedability, the fundamental concepts relating to this value and priority measure were explored through raw data analysis. From this process two distinct sets of criteria, as specific to air combat impedability, were determined. First, the ability to inflict maximum damage at a specified target was considered to be a primary contributor of air combat impedability:
 - “Defensive counter air comprises all measures designed to nullify the effectiveness of hostile air action” (Royal Australian Air Force, 2008b, p. 65).
 - “Strategic attack is the precise application of air power in offensive operations to ...destroy carefully chosen adversary targets” (Royal Australian Air Force, 2008b, p. 40).

As is documented in the statements above, the Air Combat aerial system contributes to impedability through the ability to destroy/nullify [concepts used interchangeably] specified targets. This destructive capability, as enabled by the air combat aerial kinetic weapons system, allows for permanent physical damage of the target to occur.

- ❖ A second criterion of air combat impedability is the ability to incapacitate a specified target [inclusive of its aerospace power, infrastructure, and assets] from achieving its mission plan:
 - “Defence counter air comprises all measures to reduce or neutralise the effectiveness of hostile air action and to prevent the enemy from gaining control of the air” (Royal Australian Air Force, 2008a, p. 142).

Within the context of the current analysis, the term ‘incapacitate’ is inclusive of any non-lethal action which renders a specified target ineffective for a temporary period of time. For example, this action can be achieved by reducing a target’s movements (immobilisation, restriction), or by temporarily disabling/degrading a target’s communication/sensor system. By using non-lethal methods, the Air Combat system can alter a target’s behaviour through non-fatal, reversible capabilities, ensuring permanent injury or damage to the specified target does not occur.

Glossary:

- ❖ *Attack*: To set upon with force or weapons (Macquarie Dictionary Online, 2011).
- ❖ *Degrade*: Render ineffective or unusable by impairing some or all of a capability with or without physical damage (Warfare Studies Institute, 2005, p. 41).
- ❖ *Deny*: A tactical task to prevent enemy use of a specified thing (Department of Defence, 2011).
- ❖ *Destroy*: To physically render a group or organisation ineffective unless it is reconstituted (Department of Defence, 2011).
- ❖ *Destruction*: The effect of destroying an opponent’s physical capability to do something (Butler, 2008, p. 32).
- ❖ *Incapacitation*: Renders the specific individual(s) or equipment ineffective by disabling them, inhibiting further action, and/or degrading their ability to harm our forces while minimizing fatalities, permanent injuries, and undesired damage to surrounding areas or people (US Department of Defense, n.d.).
- ❖ *Neutralise*: A tactical task to render an enemy element temporarily incapable of interfering with the operation (Department of Defence, 2011).
- ❖ *Nullify*: To make ineffective, futile, or of no consequence (Macquarie Dictionary Online, 2011).
- ❖ *Protect*: A tactical task to provide safety for an individual, group or force and prevent any loss as a result of enemy or other action (Department of Defence, 2011).

- ❖ *Suppress*: A tactical task to temporarily degrade an enemy capability to enable a friendly action (Department of Defence, 2011).
- ❖ *Weapons*: Anything serving as an instrument for making or repelling an attack (Macquarie Dictionary Online, 2011).

KNOWLEDGE

Definition of Knowledge:

'Knowledge', within an air combat context, is the ability to [obtain information](#) about a [target](#), whilst simultaneously [exploiting](#) this information and [denying](#) the adversary's ability to do the same.

Obtain:

The concept of 'obtain' is described as "to come into possession of" (Department of Defence, 2010; Macquarie Dictionary Online, 2010). Within the context of air combat knowledge, the act of obtain[ing] information is achieved by means of collecting and disseminating target specific information to and from a variety of sources.

Information:

The Royal Australian Air Force (RAAF) defines 'information' as "unprocessed data of every description which may be used in the production of intelligence" (Royal Australian Air Force, 2008b, p. 66). Though this definition encapsulates the fundamental concepts of air combat specific information, for the purposes of the current analysis a more detailed description of information is required.

As informed by document analysis, within the context of air combat knowledge, the concept of 'information' [unprocessed data] encapsulates two interconnected constructs. Firstly, information can relate to a target's [presence](#), [location](#), [classification](#), and [identity](#). Additionally, information may also refer to a target's [capabilities/limitations](#) and [intentions](#) (as informed by Royal Australian Air Force, 2008a; Royal Australian Air Force, 2008b).

- [Presence:](#)

The concept of 'presence' is defined as "the state or fact of being present" (Macquarie Dictionary Online, 2010), with 'present' described as "being in a specified place" (Collins Dictionary Online, 2010). By adopting the above definitions, presence, within the current analysis, will refer to the ability of the Air Combat system to detect the general existence of a specified target. This capability is predominantly enabled by the sensor subsystem, however the ability to communicate with ground staff and other airborne assets can provide further support in detecting the general presence of a target.

- [Location:](#)

The ability to 'locate' is described as "to set, fix, or establish in a place, situation, or locality" (Macquarie Dictionary Online, 2010), with 'location' defined as a "place or situation occupied" (Macquarie Dictionary Online, 2010). As specific to air combat knowledge, the ability to determine the exact location of a moving target (air or surface) has two primary outcomes. Firstly, it provides a sound foundation from where additional information relating to a specific target (i.e., identity, composition) can be collected, and secondly, this capability provides support to other operational requirements as related to the value and priority measures of impedability, safety, and humanity (i.e., accurate physical damage to a target achieved through correctly establishing the location of the target).

It is important to highlight that the ability to determine the 'location' of a specified target is distinct from determining presence insofar as the concept of 'presence' refers to the general existence of target (situational awareness) as opposed to determining its precise locale. As such, presence could be considered a first step in establishing target location.

- [Classification:](#)

The act of classifying something is defined as "to arrange or distribute in classes" (Macquarie Dictionary Online, 2010). As specific to the current analysis, the Air Combat system must be capable of establishing the category/class to which a target belongs to (e.g., fighter or civilian aircraft, friendly, hostile, or unknown target) so as to effectively meet the functional purpose of Air Combat (Lee, 2005).

- **Identity:**

The term 'identity' has been described as the "individual characteristics by which a person or thing is recognised" (Collins Dictionary Online, 2010). Within an air combat context, the Air Combat system must be capable of identifying a specified target based on its individual characteristics (e.g., F-22 from a Su-27) so as to support the functional purpose and other value and priority measures (e.g., impedability, safety). In addition to this, it is important to emphasise that the ability to identify a targets' identity adds an additional layer of information from that collected at the classification level.

- **Capabilities/ Limitations:**

The Oxford Dictionary Online (2012) defines 'capabilities' as "the power or ability to do something". Based on this definition, a set of capabilities are considered to be those individual abilities or characteristics which enable an entity to achieve its desired outcomes or effects. For example, an enemy fighter jet's capabilities could be measured according to its maximum speed or precise targeting. Such capabilities, if utilised correctly, may facilitate that fighter jet to achieve its mission, task, or function.

In contrast to capabilities, the concept of 'limitation[s]' has been defined as "a restriction or controlling of quantity, quality, or achievement" (Collins Dictionary Online, 2012). For the current analysis, an entity's limitations will be defined as any restricting/limiting factor (e.g., payload weight) which interferes with its ability to achieve desired outcomes or effects.

- **Intentions:**

The Department of Defence (2010) defines 'intentions' as "an aim or design (as distinct from capability) to execute a specified course of action". As with the above definition of capability, within an air combat framework, the Air Combat system is capable of collecting and disseminating information specific to a target's intentions as achieved through integrating multiple sources of information (i.e., location, classification, identity). In this case, a target's intentions can include, but are not limited to, understanding what course of action the target is likely to take and how the target will react to attack/defensive actions.

Target:

The Department of Defence (2010) defines 'target' as "the object of a particular action, for example a geographic area, a complex, an installation, a force, equipment, an individual, a group or a system". Though broad, this definition enables the concept of 'target' to capture an extensive number of physical objects, ranging from a single enemy aircraft to enemy surface facilities and environmental factors.

Exploiting /Exploit:

The concept of 'exploiting/exploit' in a knowledge context has been defined as "taking full advantage of any information that has come to hand for tactical, operational, or strategic purposes" (US Department of Defense, 2008, p. 196), with the term 'advantage' referring to "any state, circumstance, opportunity, or means specially favourable to success, interest, or any desired end" (Macquarie Dictionary Online, 2010). For air combat, the ability to exploit information enables a superior information position — a higher level of knowledge — to be achieved.

Denying/Deny:

The Department of Defence (2010) defines 'deny/denying' as "to withhold information about friendly capabilities and intentions that an enemy needs for effective and timely decision making". For air combat, the ability of the Air Combat system to withhold information from the adversary enhances the 'superiority' aspect latent within knowledge.

Measures:

- ❖ **Primary measures:**

1. Information about a target required = Information about a target obtained.
2. Exploitation of information required = Exploitation of information achieved.

3. Denial of an adversary's ability to obtain and exploit information required = Denial of an adversary's ability to obtain and exploit information achieved.

- The primary measures stated above are criteria that must be satisfied in order for the Air Combat system to achieve its functional purpose. As such, the Air Combat system must afford the ability to obtain target information, exploit this information, and deny the adversary the ability to do the same.

❖ **Secondary measures:**

1. Accurate visual observation of a target required = Accurate visual observation of a target achieved.
2. Timely visual observation of a target required = Timely visual observation of a target achieved.
3. Efficient visual observation of a target required = Efficient visual observation of a target achieved.
 - At this stage, these measures are purely illustrative examples of secondary measures for air combat knowledge. A more comprehensive description of the secondary measures will be developed in the second iteration of this model.

Rationale and supporting documentation:

- ❖ To satisfy the functional purpose of air combat, the Air Combat system must have the ability to obtain information about a specific target, whilst simultaneously exploiting this information and denying the adversary's ability to do the same. As such, the value and priority measure of knowledge captures the Air Combat systems' capacity to contribute, utilise, and enhance the RAAF's knowledge of an adversary, specified target, or operational environment to its competitive advantage:
- "Information, intelligence and knowledge build situation awareness and are the lifeblood of effective operations" (Royal Australian Air Force, 2008b, p. 33).
 - "Judging the importance of the target requires intimate knowledge of not only the commander's intent, but also the target's capabilities and relevance to the adversary's war effort" (Reynolds, 2006, p. 66).
 - "Surveillance is a continuous activity designed to enhance our knowledge of an adversary or other target and provide a warning of opponents' initiatives and significant changes in their activities" (Royal Australian Air Force, 2008a, p. 127).
- ❖ The concept of air combat knowledge is comparable to terms readily used in current and past Air Force doctrine and Defence publications, for example, 'knowledge dominance', 'knowledge edge', and 'information superiority':
- "Knowledge dominance is not, as it may seem, the simple gathering and dissemination of ever more information. It is a human driven component of warfighting: it is about using modern information technology and network-centric warfare to enable humans to better understand their environment, themselves and their enemy" (Houston, 2007, p. 7).
 - "[Information superiority is] the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same" (US Department of Defense, 2008, p. 263).
 - "...attainment of a knowledge edge is founded on a military system that successfully integrates individual and collective knowledge and skills with agile command and control systems" (Australian Defence Force, 2006a, Chapter 1, p. 5).
 - "[Information superiority is] a state that is achieved when a competitive advantage is derived from the ability to exploit a superior information position" (Alberts, Garstka, & Stein, 2000, p. 34).

Whilst important to recognise the palpable differences between that of information and knowledge¹⁸, the statements above highlight two distinct aspects inherent within knowledge dominance, knowledge edge, and information superiority: the ability to obtain information, and the usage of such information to achieve a competitive advantage over a designated adversary. For the purposes of the current analysis, the value and priority measure of knowledge will reflect an amalgamation of the above terms and the inherent concepts within them.

- ❖ Intrinsic to air combat knowledge is the capacity to obtain information about a specific target. Raw data analysis indicates the Australian Air Combat system has previously been used (F-111C), and is currently being employed (F/A-18A/B, F/A-18F) within an Intelligence, Surveillance, and Reconnaissance (ISR)¹⁹ framework:
 - “The long-awaited F-111s arrived at Amberley in four delivery flights, the first on June 1, 1973, and the last on December 4 that year. Originally intended for interdiction and maritime/land strike roles, the F-111’s multi-role capabilities have been recognised and today’s F-111 aircrew are trained in air control, reconnaissance (both strategic and tactical) and air support to ground and naval forces” (Liebelt, 2002).
 - “With its electro-optical, infra-red and radar imaging systems, the F/A-18F Super Hornet provides the RAAF with a flexible, responsive and survivable non-traditional ISR capability” (Royal Australian Air Force, 2011).
 - “The Super Hornet gives the RAAF the capability to conduct air-to-air combat, strike targets on land and at sea, suppress enemy air defences and conduct reconnaissance” (Department of Defence, 2012).

Additionally, fifth generation air combat platforms, like the F-35, are expected to function within an ISR paradigm once operational:

- “Joint Strike Fighter’s (JSF) combination of stealth, advanced sensors, networking and data fusion capabilities, when integrated into the networked Australian Defence Force, will ensure Australia maintains its strategic capability advantage out to 2030” (Defence Materiel Organisation, 2009, p. 3).
- “To conduct operations successfully, Defence will increasingly need to merge information from many sources and deployed assets. These will include...the JSF aircraft (which will have unprecedented ISR capabilities for a combat aircraft)” (Department of Defence, 2009, p. 82).

These statements suggest that Australia’s previous, present, and future air combat platforms have the capacity to perform a reconnaissance and surveillance function within the RAAF/Australian Defence Force (ADF). However, the exact means through which the Air Combat system supports RAAF’s reconnaissance and surveillance requirements, and thereby supports knowledge, needs to be determined.

- ❖ Surveillance, by definition, is the “systematic observation of aerospace, surface or sub-surface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means” (Department of Defence, 2011). The Air Combat system contributes to surveillance by having the capacity to detect and observe targets (e.g., environmental characteristics, enemy platforms) at an extended distance from a target (i.e., beyond visual range; Moir & Seabridge, 2006) and in airspace which is generally inaccessible to traditional ISR assets²⁰ (e.g., Airborne Early Warning and Control (AEW&C) aircraft, AP-3C Orion) (US Air Force,

¹⁸ Loch, Hinchcliffe, Kainikara, and Clarke (2008) define information as “useful data”, with data described as “symbols that represent objects and events, and their properties” (p. 7). Comparatively, the concept of knowledge is the “application of data and information” (p. 7) in the form of “instructions and know-how” (p. 7). As specific to the current analysis, the Air Combat system is capable of collecting specific types of information, thereby enabling ‘knowledge’ to be achieved.

¹⁹ “A collection activity that synchronises and integrates the acquisition, processing and provision of information and single source intelligence by sources and agencies tasked to satisfy a collection requirement” (Department of Defence, 2010).

²⁰ Based on their design characteristics, the Air Combat system has operational access to areas of the battlespace (i.e., where enemy targets operate) that are denied to traditional ISR aircraft (US Air Force, 2007), and therefore has access to unique collection opportunities (Williams, 2007).

2007; Williams, 2007). As such, information relating to the general presence of a target can be obtained, thereby affording aspects of air combat knowledge.

- ❖ Distinct from surveillance, reconnaissance is "...undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy, or to secure data concerning the meteorological, hydrographic, or geographic characteristics of a particular area" (Department of Defence, 2011). Within the context of the current analysis, the Air Combat system contributes to reconnaissance by having the ability to collect precise information relating to a specific target. 'Precise' information within this framework can refer to a target's location, classification, identity, capabilities/limitations, or intentions.
- ❖ To achieve the previously mentioned unique capabilities that the Air Combat system affords to knowledge, the sensor and communication subsystems are used to obtain information by way of its collecting and disseminating capabilities:
 - "The APG-79 [employed on the F/A-18F] active electronically scanned array (AESA) radar provides significantly more capability for threat detection and precise identification and location accuracy" (Williams, 2007, p. 11).

As demonstrated in the previous statement, the Air Combat system uses its sensor subsystem (inclusive of radar, infra-red, etc.) to collect high-resolution imagery and electronic data. Such imagery or electronic data can form the basis of information related to a targets' location, classification, identification, capabilities, and intentions (Royal Australian Air Force, 2008a; Royal Australian Air Force, 2008b). Moreover, information sourced from the Air Combat systems' sensors can provide a generalised representation of the battlespace, thus enhancing knowledge of the airspace/surface environment and of the potential presence of enemy targets.

- ❖ In order for information collected from the sensor subsystem to be effectively utilised, and ultimately enable knowledge to be achieved, the Air Combat system must have efficient communication capabilities to provide rapid data dissemination to decision makers and analysts (Williams, 2007):
 - "Their [F-22 and F-35A] ability to distribute information at high speed enables them to provide advanced surveillance" (Defense Industry Daily, 2005).

For air combat, the communication subsystem enables real time information to be fed to the relevant agencies, ultimately informing the information aspect of air combat knowledge.

- ❖ In addition to obtaining information, air combat knowledge encompasses the ability to gain a competitive advantage over an adversary through use, or denial, of information (Royal Australian Air Force, 2008a). As specific to the Air Combat system, the means through which knowledge is achieved is by exploiting information against an adversary and denying access to that same level of information (Alberts et al., 2000; US Department of Defense, 2008):
 - "Air Force's approach to all levels of knowledge must focus on: assuring its availability and accuracy; managing its collection, analysis and dissemination; exploiting the understanding it provides; and, where possible, employing that understanding as a weapon against an adversary" (Royal Australian Air Force, 2008b, p. 33).
 - "Information operations coordinate offensive and defensive actions in the information domain to create effects on the understanding, will and capability of adversaries. These operations degrade adversaries' capability to carry out information-based activities" (Royal Australian Air Force, 2008a, p. 129).

As the above statements posit, the ability to 'exploit' and 'deny' the adversary are the intrinsic links between obtaining information (information aspect) and achieving a "winning edge" (the ultimate goal for knowledge) (Department of Defence, 2009, p. 61). To attain this end, information must be of an accurate, timely, and efficient nature (Royal Australian Air Force, 2008a, p. 113), with specific information relative to the adversary being utilised (i.e., exploited) prior to the adversary becoming aware of it (Butler, 2008).

- ❖ To satisfy the requirements of knowledge as a value and priority measure, the Air Combat system must be capable of exploiting information so as to gain a competitive advantage over an adversary. To this end, the act of exploiting information may result in targeting vulnerabilities in an adversary's defence or by altering its [the Air Combat system] own behaviour or that of friendly forces to effectively utilise a superior information position:
 - Electronic support is "that division of electronic warfare involving actions taken to search for, intercept, locate, record, and analyse radiated electromagnetic energy for the purpose of exploiting such radiations in support of military operations" (Department of Defence, 2011).
- ❖ In addition to exploiting information, the Air Combat system must also be capable of denying an adversary access to its information (e.g., location, capabilities) or that of friendly forces. By actively withholding this information, an adversary's decision making ability is impeded, thereby further extending an 'edge' over the adversary:
 - "Security is vital in military operations to allow friendly forces to operate effectively with minimal interference from the enemy and deny the enemy the advantage" (Royal Australian Air Force, 2008a, p. 44).
 - "Defensive counter air aims to complicate an adversary's counter air operations by denying information, providing timely threat detection and protecting friendly forces from kinetic, electronic or other attack" (Royal Australian Air Force, 2008a, p. 143).

Glossary:

- ❖ *Adversary*: A party acknowledged as potentially hostile to a friendly party and against which the use of force may be envisaged (Department of Defence, 2011).
- ❖ *Advantage*: Any state, circumstance, opportunity, or means specially favourable to success, interest, or any desired end (Macquarie Dictionary Online, 2011).
- ❖ *Competitive*: Of, relating to, involving, or decided by competition (Macquarie Dictionary Online, 2011).
- ❖ *Dominance*: Rule, control, authority, ascendancy (Macquarie Dictionary Online, 2011).
- ❖ *Information Operations*: The coordination of information effects to influence the decision-making actions of a target audience and to protect and enhance our decision-making and action in support of national interests (Royal Australian Air Force, 2008b, p. 67).
- ❖ *Superior*: Of higher grade or quality (Macquarie Dictionary Online, 2011).

SAFETY

Definition of Safety:

The concept of 'safety', within the context of air combat, is defined as the ability to [preserve human](#) and [material resources](#) concentrated within the Air Combat system, and those [friendly forces](#) with which the Air Combat system interacts with (Australian Defence Force, 2009, p. 87). Specifically, the Air Combat aerial system must have the capacity to ensure the preservation of air combat power (Department of Defence, 2001, p. 3), as achieved by protecting the air combat aircraft, air combat aircrew, and friendly forces.

[Preserve/preservation:](#)

The Macquarie Dictionary Online (2011) defines the term 'preserve' as the ability to "keep alive or in existence" or to "keep safe from harm or injury". The former definition focuses upon avoiding fatal consequences. The latter definition encapsulates avoiding non-fatal consequences. For purposes of the current analysis, 'preserve' will encompass both definitions as existing upon a continuum.

[Human resources:](#)

The concept of 'human resources' has previously been described as "the human component of an organisation, institution, business, country" (Macquarie Dictionary Online, 2011). For air combat safety, the human component entity of the Air Combat system is the aircrew²¹. Specific to the current analysis, the aircrew of the Air Combat system will encompass the air combat pilots and air combat officers (navigators).

[Material resources:](#)

'Material' has been defined as "the substance or substances of which a thing is made or composed" (Macquarie Dictionary Online, 2011), with 'resources' described as "a source of supply, support, or aid" (Macquarie Dictionary Online, 2011). For the current analysis, the Air Combat aerial system [airborne Air Combat aircraft²²], as inclusive of its subsystems (e.g., navigation system) and components (e.g., radar), will be considered the material resources entity for air combat.

[Friendly forces:](#)

The term 'friendly' generally refers to personnel and assets which belong to, or are allied with, one's own defence force (definition informed by Macquarie Dictionary Online, 2011; US Department of Defense, 2008), with 'force[s]' described as a "group of people organised for particular duties or tasks" (Collins Dictionary Online, 2011). In the context of the current analysis, the concept of 'friendly forces' encapsulates any RAAF, ADF, or allied²³ personnel or assets which operate within the Air Combat sphere (e.g., AEW&C aircraft, US Army personnel).

Measures:

❖ **Primary measures:**

1. Preservation of air combat aircraft required = Preservation of air combat aircraft achieved.
2. Preservation of air combat aircrew required = Preservation of air combat aircrew achieved.
3. Preservation of friendly forces' personnel and assets required = Preservation of friendly forces' personnel and assets achieved.

²¹ The concept of 'aircrew' has been defined as "persons operating an aircraft in flight" (Macquarie Dictionary Online, 2010, based on definition of 'crew').

²² The term 'aircraft' has been defined as "any machine supported for flight in the air by buoyancy or by dynamic action of air on its surfaces" (Macquarie Dictionary Online, 2011). Based on this definition of aircraft, an 'air combat aircraft' will be described as any aircraft which is capable of performing an airborne combat function in accordance with the Air Combat Capability functional purpose.

²³ The term 'allied' is the adjective of 'alliance'. Alliance is defined as the "relationship that results from a formal agreement (e.g., treaty) between two or more nations for broad, long-term objectives that further the common interests of the members" (US Department of Defense, 2008, p. 31).

- The primary measures stated above are criteria that must be satisfied in order for the Air Combat system to achieve its functional purpose. As such, the Air Combat system must ensure the ongoing preservation of the air combat aircrew (human resources), the air combat aircraft (material resources), and the friendly forces which operate within the Air Combat sphere.
- ❖ **Secondary measures:**
1. Accurate navigation of the aircraft to a specified location required = Accurate navigation of the aircraft to a specified location achieved.
 2. Timely navigation of the aircraft to a specified location required = Timely navigation of the aircraft to a specified location achieved.
- At this stage, these measures are purely illustrative examples of secondary measures for air combat safety. A more comprehensive description of the secondary measures will be developed in the second iteration of this model.

Rationale and supporting documentation:

- ❖ Safety is a value and priority measure for the Air Combat system. The Air Combat system must preserve longevity of air combat aircraft, air combat aircrew, and friendly forces in order to achieve its functional purpose. More specifically, to attain and maintain operational effectiveness (i.e., protecting Australia from attack), the Air Combat system must minimise vulnerability of human and material resources concentrated within its system (inclusive of friendly forces—see above definition):
- “Modern air forces can scarcely afford to suffer anything greater than a low incidence of losses, in both personnel and material, and there are inherent lethal risks involved to aircrew in the pursuit of the physical destruction of an adversary” (Butler, 2008, p. 23-24).
 - “From a war perspective, we want everybody to be able to fight safely, maintain operational capability and return home in good health” (Royal Australian Air Force, 2004b, p. 10).
- ❖ The definition of ‘safety’ within an air combat context is different to that described by Air Force documents:
- “The control of recognised hazards to attain an acceptable level of risk” (Department of Defence, 2011).
 - “A state in which the risk of harm (to persons) or damage is limited to an acceptable level” (Royal Australian Air Force, 2004b, p. 12).
- The above definitions are based within a generalist framework of ‘safety’ and consequently are not necessarily reflective of the specific safety concerns relevant to the Air Combat system. To determine the exact contribution safety affords to air combat, Air Force and Defence publications were analysed.
- ❖ Based on raw data, it was determined that the ongoing protection of RAAF personnel and material resources during peacetime training or in conflict were of primary importance:
- “The ultimate aim of aviation safety within the ADF is the preservation of human and material resources to generate combat capability in all ADF aviation operations” (Australian Defence Force, 2009, p. 87).
 - “In peacetime training or in conflict, the loss of any of our people or an aircraft in an aviation accident is not acceptable” (Australian Defence Force, 2009, p. 3).
 - “In the Australian context, where our forces cannot afford heavy attrition and we place a high value on life, appropriate and balanced effort must be spent in force protection” (Royal Australian Air Force, 2008b, p. 36).

- “The Government’s aim in the development of strike capability is to ensure that we have the capability to contribute to the defence of Australia by attacking military targets within a wide radius of Australia, against credible levels of air defences, at an acceptable low level of risk to aircraft and crew” (Department of Defence, 2000, p. 92).

As the above statements demonstrate, aviation safety hinges on the ability to protect human (e.g., RAAF personnel) and material (e.g., airborne assets, ground based facilities, equipment) resources when undertaking operational requirements. Within the context of air combat, the preservation of the airborne air combat aircraft (material resources) and its crew (human resources) is required to generate and deploy air combat power. Moreover, the safety of personnel and assets as belonging to friendly forces must also be considered within the concept of safety.

- ❖ For the current analysis, preservation of human resources within an air combat safety context can be considered to exist upon a continuum. That is, the ‘safety’ of the aircrew can encompass avoiding loss of life (i.e., fatal consequences) through to avoiding injury, illness, or overwork (i.e., non-fatal consequences):
 - “Basic safety principles lie in the fundamental ethos of not wanting people to get hurt. Whether at war or peace, we have a duty of care to personnel to minimise their risk from harm” (Royal Australian Air Force, 2004b, p. 10).
 - “One of the goals of Defence is to achieve zero aviation accidents and serious accidents resulting from organisational and systemic deficiencies” (Australian Defence Force, 2009, p. 83).

As implicitly stated above, the concept of ‘fratricide’ is embedded within the value and priority measure of safety. As defined by the Department of Defence (2011), fratricide is “the unintentional killing or wounding of friendly personnel by friendly firepower”. As such, fratricide encompasses the safety of friendly personnel.

- ❖ As described above, the material resources of the Air Combat system is specific to the subsystems and components of the airborne air combat aircraft. Based on raw analysis, the preservation of the material resources (in this case the Air Combat aerial system) is required to achieving the overall functional purpose:
 - “Force protection describes the actions taken to minimise the vulnerability of deployed and home-based personnel, facilities, material, information and operations from the threat posed by an adversary or the environment while preserving the freedom of action and operational effectiveness of the force” (Royal Australian Air Force, 2008a, p. 114).
 - “For air platforms, lack of effective self-protection can make the air vehicle undeployable due to vulnerability, placing a premium on ensuring air vehicles are acquired with self-protecting systems and that those systems are upgraded to keep pace with emerging threats through an air vehicle’s service life” (Royal Australian Air Force, 2008b, p. 36).

These statements highlight the importance of minimising the vulnerability²⁴ of material resources in achieving Air Force safety. For air combat, preservation of material resources can extend from avoiding temporary disruption or long-term (fatal) destruction of the Air Combat system.

- ❖ It is important to highlight that whilst air combat safety is of primary importance to the Air Combat system, there is always an element of risk in effectively implementing air combat power:
 - “Military aviation operations, exercises and training by their nature must involve some level of risk to achieve success, but our planning and execution must be thorough to

²⁴ Vulnerability is defined as “susceptible to being wounded, liable to physical hurt, open to attack or assault” (Macquarie Dictionary Online, 2011).

ensure the risks are as low as reasonably practicable to achieve each mission” (Australian Defence Force, 2009, p. 3).

- “The military operates in a high-risk environment where the ultimate outcome may be to destroy another nation’s military capability and capacity” (Australian Defence Force, 2009, p. 43).

As the above statements articulate, aviation operations, especially air combat operations, involve some element of risk to achieve success. As specific to the current value and priority measure, the concept of ‘risk’ must be considered as an embedded fundamental construct for air combat.

Glossary:

- ❖ *Air Force Safety*: This is the management of the health and safety of all people in Air Force workplaces in the air and on the ground with an aim of keeping them free of injury and disease (Royal Australian Air Force, 2004b, p. 11).
- ❖ *Aviation safety*: A state in which the risk of harm (to persons) or damage is limited to an acceptable level with regard to the activity of operating aircraft, or of designing, producing and maintaining them (Royal Australian Air Force, 2004b, p. 11).
- ❖ *Fatal*: Causing death; causing destruction or ruin (Macquarie Dictionary Online, 2011).
- ❖ *Hazard*: A source or a situation with a potential for harm in terms of human injury or ill health, damage to property, damage to the environment, or a combination of these (Royal Australian Air Force, 2004b, p. 12).
- ❖ *Non-fatal*: Bodily harm resulting from severe exposure to an external force or substance (mechanical, thermal, electrical, chemical, or radiant) or submersion. This bodily harm can be unintentional or violence-related (US Department of Health and Human Sciences, Centers for Disease Control and Prevention, 2007).
- ❖ *Risk*: The possibilities of adverse outcomes, usually by way of deliberate actions, unforeseen environmental factors, miscalculation or other human error (Department of Defence, 2011).

HUMANITY

Definition of Humanity:

The concept of 'humanity' for the Air Combat aerial system is defined as the ability to [preserve](#) the [civilian population](#) and its [infrastructure](#) (as informed by Australian Defence Force, 2006b; Royal Australian Air Force, 2004a).

[Preserve/preservation:](#)

The Macquarie Dictionary Online (2010) defines the term 'preserve' as the ability to "keep alive or in existence" or to "keep safe from harm or injury". The former definition focuses upon avoiding fatal consequences, whereas the latter definition focuses upon avoiding non-fatal consequences. For the purposes of the current analysis, the concept of 'preserve' encompasses the avoidance of [unnecessary suffering](#), [injury](#), or [destruction](#) of the civilian population and its infrastructure.

- [Unnecessary:](#)

The Collins Dictionary Online (2010) describes the term 'unnecessary' as that which is "not essential", with 'essential' defined as "vitally important, absolutely necessary" (Collins Dictionary Online, 2010). In accordance with the Law of Armed Conflict (LOAC) and the Rules of Engagement (ROE), the Air Combat system must act within the bounds of necessity seeking to ensure the minimisation of harm directed at civilians and civilian infrastructure while still achieving the functional purpose.

- [Suffering:](#)

The Macquarie Dictionary Online (2010) defines the concept of 'suffering' as the "act of someone who suffers", with 'suffer' described as "to undergo or feel pain or distress" or to "sustain injury, disadvantage or loss" (Macquarie Dictionary Online, 2010). These definitions suggest the experience of suffering to be associated with the affective, psychological response of unpleasantness which may be the result of harm or the threat of it (as informed by the Stanford Encyclopaedia of Philosophy, 2006). As specific to the current analysis, the act of suffering may be inflicted by physical pain/injury, destruction of life or infrastructure, and social and economic instability.

- [Injury:](#)

The term 'injury' has been defined as "physical hurt" (Collins Dictionary Online, 2010), which can include but is not limited to "fractures, wounds, sprains, dislocations, concussions, compressions, extremes of temperature or prolonged exposure, or exposure to toxic or poisonous substances" (Department of Defence, 2010). For the purposes of the current analysis, the Air Combat aircraft must refrain from causing unnecessary injurious effects (as noted above) as directed at the civilian population.

- [Destruction:](#)

The concept of 'destruction' is defined as "the fact or condition of being destroyed" (Macquarie Dictionary Online, 2010), with the term 'destroy[ed]' described as "to render ineffective". Within the context of the current analysis, the act of 'destruction' is inclusive of both civilian life and civilian infrastructure as demonstrated by concepts relating to collateral/incidental damage.

[Civilian population:](#)

The International Committee of the Red Cross (1977) defines a 'civilian' as "any person who is not a member of the armed forces" (Article 50), with 'civilian population' comprising "all persons who are civilians" (Article 50). For the purposes of the current analysis, these descriptions will be used in defining a 'civilian population' and 'civilians'.

[Civilian infrastructure:](#)

The concept of 'civilian infrastructure' can be defined as fixed or permanent installations, fabrications, or facilities that are not used to achieve military objectives (definition informed by the Department of Defence [2010]; International Committee of the Red Cross, 1949; International

Committee of the Red Cross, 1977; Macquarie Dictionary Online [2010]). Within this context, the term 'military objectives' are "those objects which by their nature, location, purpose or use make an effective contribution to military action and whose total or partial destruction, capture or neutralization, in the circumstances ruling at the time, offers a definite military advantage" (International Committee of the Red Cross, 1977, Article 52). Examples of civilian infrastructure may relate to hospitals, schools, and churches.

Measures:

❖ Primary measures:

1. Preservation of the civilian population required = Preservation of the civilian population achieved.
2. Preservation of civilian infrastructure required = Preservation of civilian infrastructure achieved.
 - In accordance with the primary measures listed above, the Air Combat system must ensure the constant preservation of the civilian population and its infrastructure so as to achieve the functional purpose.

❖ Secondary measures:

1. Accurate delivery of weapons at a target required = Accurate delivery of weapons at a target achieved.
2. Timely delivery of weapons at a target required = Timely delivery of weapons at a target achieved.
 - At this stage, these measures are purely illustrative examples of secondary measures for air combat humanity. A more comprehensive description of the secondary measures will be developed in the second iteration of this model.

Rationale and supporting documentation:

- ❖ The Air Combat system must be able to preserve civilian life and civilian infrastructure in order to achieve its functional purpose. The reason for this position goes beyond mere adherence to international laws and treaties. To a limited extent, respect for humanity in the RAAF may be a result of an Australian defence culture that aims to be a "force for good" (Department of Defence, 2002, p.1) and seeks to take the "moral high ground" (Department of Defence, 2002, p. 1), when and where required. This principle is, however, most likely to have its origins in the values and ideals of the broader community in which Defence operates:
 - "In the complex arenas of politics and international relations, perceptions and force hold great sway, and in order to retain internal and external support for anything the military does it must be perceived that military action is accomplished with the highest possible moral standing" (Pender, 2004, p. 7).
 - "The weighty treatment given to application of ROE by RAAF F/A-18 aircrew during Operation Falconer is demonstrative of the importance that the media and the public give to collateral damage prevention" (Reynolds, 2004, p. 66).
 - "... it is important that military individuals and organisations are regulated so that they do not use these skills for purposes contrary to societal expectations" (Pender, 2004, p. 1).
- ❖ In order to better understand the specific contribution air combat affords to humanity, the fundamental concepts relating to this value and priority measure were explored through raw data analysis. First, it was determined that the Air Combat system is obligated under operational and international law (e.g., LOAC) to preserve the civilian population and civilian infrastructure when undertaking operational requirements:
 - "All feasible precautions must be taken to avoid loss of civilian life, injury to civilians and damage to civilian objects" (Royal Australian Air Force, 2004a, p. 64).

- “Protocol I [1977] expressly provides that the civilian population and civilian objects are to be protected against attack. Acts or threats of violence primarily intended to spread terror among the civilian population are prohibited. Reprisal actions against civilians are also prohibited” (Royal Australian Air Force, 2004a, p. 65).
- “RAAF personnel do not need to be told that it is wrong to target hospitals and churches, or that it is illegal to kill unarmed civilians or shoot prisoners of war” (Royal Australian Air Force, 2004a, p. 47).

As the above statements demonstrate, the concept of air combat humanity is based on the systems’ ability to preserve the civilian population and its infrastructure. Within the current framework, the concept of ‘preserve’ refers to the avoidance of both non-fatal and fatal outcomes, be it the destruction of a civilian hospital, loss of civilian life, or the experience of social, economic, or psychological suffering as a result of the aforementioned fatal/non-fatal outcomes.

- ❖ As specific to the Air Combat system, appropriate use of weaponry must be employed in order for the value and priority measure of humanity to be respected:
 - “The employment of weapons, material and methods of warfare that are designed to cause superfluous injury or unnecessary suffering is prohibited. A corollary is that weapons, which by their nature are incapable of being directed against military objects, are forbidden due to their indiscriminate effect” (Royal Australian Air Force, 2004a, p. 73).
 - “Missiles and projectiles which are dependent on over-the-horizon or beyond-visual-range guidance systems are lawful. However, their use requires careful judgment that must include consideration of risk to innocent or protected personnel, objects, facilities or units” (Royal Australian Air Force, 2004a, p. 74).
- ❖ Though the Air Combat system will always strive to achieve a zero civilian casualty and zero infrastructure destruction policy, there are always risks associated with airborne air combat operations. The applicable operational (e.g., ROE) and international laws of war (e.g., LOAC) for air combat consider these risks in achieving the functional purpose:
 - “An attack on a military objective is not indiscriminate or otherwise unlawful simply because there is a risk of incidental injury or collateral damage. The expected extent of such injuries or damage must not, however, be disproportionate to the concrete and direct military advantage anticipated from the attack” (Royal Australian Air Force, 2004a, p. 64).
 - “Incidental injury and collateral damage may be the inevitable results of aerial attack. This fact is recognised by LOAC and, accordingly, it is not unlawful to cause such injury and damage” (Royal Australian Air Force, 2004a, p. 65).
 - “Commanders are obliged to take all feasible precautions, taking into account military and humanitarian considerations, to keep civilian casualties and damage to a minimum consistent with mission accomplishment, and aircrew safety” (Royal Australian Air Force, 2004a, p. 65).
- ❖ As indicated in the statements above, the risk of incidental injury or collateral damage to the civilian population and its infrastructure must be proportionate²⁵ to achieving the goal of the operation. As such, the Air Combat system must employ appropriate courses of action to balance two competing goals: the need to use force effectively to accomplish the mission objectives, and the need to avoid unnecessary force²⁶. Therefore, whilst air combat humanity encapsulates the preservation of the civilian population and civilian infrastructure, this

²⁵ Proportionality is defined as “the link between humanity and military necessity. A commander is not allowed to cause damage and inflict suffering which is disproportionate to the military need. Proportionality requires a commander to weigh the military value arising from the success of the operation against the possible harmful effects to protected persons and objects” (Royal Australian Air Force, 2004a, p. 50-51).

²⁶ Avoiding unnecessary force is characterised by verifying the target to be of military value, and where the act of force is proportionate and legitimate to achieving the mission objective.

criterion must be balanced against the other value and priority measures (e.g., impedability, knowledge) to ultimately achieve the functional purpose. The measures of air combat humanity reflect what the Air Combat system must strive to do (i.e., preservation of the civilian population required = preservation of the civilian population achieved); however, these measures must be considered and traded against the other value and priority measures of air combat.

RESOURCE EFFICIENCY

Definition of Resource Efficiency:

'Resource efficiency' denotes the ability to [conserve](#) the [use](#) of [expendable material resources](#) concentrated within the Air Combat system. Specifically, the Air Combat system must have the capacity to ensure the availability of fuel, weaponry, and countermeasure expendables, when and where required, in order to provide sustained air combat power.

Conserve:

The capacity to 'conserve' has been defined as "to keep and protect something from damage, change, or waste" (Cambridge Dictionary Online, 2011) or "to avoid wasteful or destructive use of" (Merriam-Webster Dictionary Online, 2011). To respect air combat resource efficiency, the Air Combat system must be capable of ensuring the appropriate use (minimisation of waste) of its expendable material resources, and in so doing balancing such resources against current and future requirements.

Use:

The term 'use' is defined as "to put into service or action, employ for a given purpose" (Collins Dictionary Online, 2011). Air combat resource efficiency requires all expendable material resources be used in a manner in keeping with their primary purpose (e.g., kinetic weapons employed against a specified target), so as to ensure their availability when required, and reduce excessive use.

Expendable:

The Macquarie Dictionary Online (2011) describes the term 'expendable' as that which is "capable of being sacrificed to achieve an objective" and "normally consumed in use". Specific to the Air Combat system, material resources of an expendable nature encapsulate air combat aircraft resources of a limited nature. Currently, this includes fuel, weaponry (e.g., missiles), and countermeasures (e.g., decoys, chaffs).

Material resources:

The term 'material' has been defined as "the substance or substances of which a thing is made or composed" (Macquarie Dictionary Online, 2011), with 'resource' described as "a source of supply, support, or aid" (Macquarie Dictionary Online, 2011). As specific to this value and priority measure, material resources are analogous to entities of an expendable nature²⁷.

Measures:

❖ **Primary measures:**

1. Expendable material resources required = Expendable material resources available.
 - The primary measure stated above is the criterion that must be satisfied in order for the Air Combat system to achieve its functional purpose. This measure assumes that the Air Combat system must have the ability to access expendable material resources (e.g. fuel, weapons, self protection systems) when required so as to support the functional purpose.

❖ **Secondary measures:**

1. Accurate navigation of the aircraft to a specified location required = Accurate navigation of the aircraft to a specified location achieved.
2. Timely navigation of the aircraft to a specified location required = Timely navigation of the aircraft to a specified location achieved.

²⁷ It is important to highlight that 'material resources' within the context of air combat resource efficiency is used to define resources of an expendable, limited nature. This is distinct to that described within the context of air combat *safety*, which equates material resources to be any entity located within the Air Combat system (i.e., all subsystems and components).

3. Efficient navigation of the aircraft to a specified location required = Efficient navigation of the aircraft to a specified location achieved.
 - At this stage, these measures are purely illustrative examples of secondary measures for air combat resource efficiency. A more comprehensive description of the secondary measures will be developed in the second iteration of this model.

Rationale and supporting documentation:

- ❖ The Air Combat system must have the ability to conserve the use of expendable material resources to fulfil its functional purpose. More specifically, the Air Combat system must be capable of balancing limited resources against operational requirements, to achieve continued air combat power. To this end, all fuel, weaponry, and countermeasure expendables must be employed as specific to their primary purpose, whilst avoiding wastage:
 - “Wasteful allocation of resources unnecessarily increases the costs of war, and carries with it the danger that it may, in some cases, threaten the achievement of the aim” (Australian Defence Force, 2005, Chapter 4, p. 6).
 - “Economy of effort is the prudent allocation and application of Defence and civil resources to achieve the desired results” (Australian Defence Force, 2005, Chapter 4, p. 6).
- ❖ To better understand the specific contribution air combat affords to resource efficiency, the fundamental concepts relating to this value and priority measure were explored through raw data analysis. From this process it was first determined that consideration of material resources at a systems level is a necessity in generating and deploying efficient air combat power:
 - “A critical function of combat support in an expeditionary context will be the ability to raise and sustain deployed combat support services including fuel, armaments and operational maintenance” (Royal Australian Air Force, 2008b, p. 47).

Statements like those noted above highlight the relationship between resources and the level of effectiveness and efficiency in achieving the overall objective. For the purposes of this analysis, effectiveness and efficiency refer to the extent to which the air combat functional purpose is achieved without being impeded by the physical limitations of expendable material resources (e.g., inefficient use of missiles = target destruction is not achieved). As inferred from the above documentation, access to material resources increases the likelihood of ongoing operational success. This supports inclusion of this concept as a value and priority measure for air combat.

- ❖ A second relevant concept for this value and priority measure is that of material resource availability:
 - “...planning also ensures the most efficient allocation of Australia's numerically limited, but high-capability, air power resources” (Royal Australian Air Force, 2008a, p. 118).
 - “The resources available to develop the Air Force's capability are finite” (Royal Australian Air Force, 2008a, p. 101).

As documented in the raw data above, to respect resource efficiency as a value and priority measure, and to achieve the overall functional purpose, the requisite material resources must be available for use. For the current analysis, the Air Combat system requires access to fuel, weaponry, and countermeasure expendables to fulfill its operational obligations and respect the other value and priority measures. Access to such material resources is solely dependent on accountability of use (i.e., no wastage), thereby securing its availability when required.

Glossary:

- ❖ *Accountable*: Responsible to someone or for some action (Collins Dictionary Online, 2011).

- ❖ *Effective*: Serving to effect the purpose; producing the intended or expected result (Macquarie Dictionary Online, 2011).
- ❖ *Efficient*: Effective in the use of energy or resources; producing an effect, as a cause (Macquarie Dictionary Online, 2011).
- ❖ *Expendable supplies and materials*: Supplies that are consumed in use, such as ammunition, paint, fuel, cleaning and preserving materials, surgical dressings, drugs, medicines, etc., or that lose their identity, such as spare parts, etc. (US Department of Defense, 2008, p. 195-196).

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Appendix D: Air Combat Capability Purpose-related Functions Analyst Documentation

This appendix presents an unclassified version of the analyst documentation developed for the Air Combat Capability purpose-related functions. Each function is defined, with a rationale and supporting documentation provided.

DESTRUCTION

Definition of Destruction:

'Destruction' is defined as the ability of the Air Combat system to [destroy](#) a specified [entity](#) beyond [functionality](#) or [restoration](#) (as informed by the Department of Defence, 2012).

Destroy:

The Macquarie Dictionary Online (2012) defines 'destroy' as "to reduce to pieces or to a useless form". Within the context of air combat destruction, 'destroy' is measured by the extent to which a specified entity cannot [function](#) nor be [restored](#) to its intended condition without being rebuilt. Such outcomes are desirable as they can reduce an enemy entity's ability to generate and project air and/or ground power. Kinetic weaponry, such as air-to-air missiles or laser-guided bombs, are currently²⁸ utilised to achieve these outcomes.

- Function/functionality:

One direct outcome of air combat destruction is the removal of an entity's functionality. As defined by the Macquarie Dictionary (2012), 'functionality' is "the purpose designed to be fulfilled by a device, tool, machine etc.". As such, the Air Combat system must be capable of removing a specified entity's primary function for destruction to be achieved. This may include, for example, the flight functionality of an enemy fighter jet, or the information exchange functions of a command and control centre.

- Restored/restoration:

A further outcome of air combat destruction – linked to the definition above – is the ability to destroy a specified entity beyond restoration. The Macquarie Dictionary Online (2012) defines 'restored' as "to bring back to a former, original, or normal condition". As such, the Air Combat system must have the capacity to destroy a specified entity to the extent that its original condition and function cannot be reinstated without being entirely reconstructed.

Entity:

As defined by the Macquarie Dictionary Online (2012), an 'entity' is "something that has a real existence; a thing, especially when considered as independent of other things". Within the current analysis, an 'entity' is generally synonymous with a combat [target](#).

- Target:

The Department of Defence (2012) defines 'target' as "the object of a particular action, for example a geographic area, a complex, an installation, a force, equipment, an individual, a group or system". This broad definition captures an extensive number of physical objects, for example [personnel](#), [material](#), or [capabilities](#).

- Personnel:

The term 'personnel' is described as "those individuals required in either military or civilian capacity to accomplish the assigned mission" (Department of Defence, 2012).

- Material:

'Material' has been described as "the substance or substances of which a thing is made or composed" (Macquarie Dictionary Online, 2012), with 'thing' defined as a "material object without life or consciousness" (Macquarie Dictionary Online, 2012). Based on the above definitions and sub-definitions, the current analysis will refer to 'material' as any object devoid of life/consciousness. This may include, for example, platforms (e.g., Sukhoi T-50) or facilities.

²⁸ Within the Air Combat Capability analysis, the destruction function is solely enabled by the weapons subsystem. At present, the weapons subsystem only consists of those technologies which are currently represented on an Australian air combat aircraft (e.g., air-to-air missiles, cannons). Inclusion of emerging or future based weapon technologies will be considered in further iterations of the analysis.

- **Capability:**

The Oxford Dictionary Online (2012) defines 'capability' as "the power or ability to do something". Based on this definition, a capability is considered to be an individual ability or characteristic which enables an entity to achieve its desired outcome or effect. For example, an enemy fighter jet's capabilities could be measured according to its maximum speed or precise targeting. Such capabilities, if utilised correctly, may facilitate that fighter jet to achieve its mission, task, or function.

Rationale and supporting documentation:

- ❖ To satisfy the functional purpose of air combat, the Air Combat system must have the ability to destroy an entity beyond functionality or restoration. Capacity to inflict this level of destruction ensures that an entity is no longer a threat²⁹ to the Air Combat system. To achieve this end, the Air Combat system must have access to kinetic weaponry:
 - "For the RAAF, the use of weapons with a kinetic effect is the primary means to affect an adversary target system and is likely to remain so in the foreseeable future" (Butler, 2008, p. 27).
- ❖ The concept of destruction is aligned with the wider priorities of the Royal Australian Air Force (RAAF) and Australian Defence Force (ADF) to fulfill the national strategic objectives as outlined by the Australian Government:
 - "The primary role of military forces is to ensure national security and defend the nation's interests through the application of lethal force" (Kainikara, 2011, p. 3).
 - "Australia's air combat capability is a vital part of our national security framework" (Smith, 2012).
 - "The ADF is the only agency of the Government that is empowered to apply lethal force in such operations to defend Australia's people, interests and way of life" (Royal Australian Air Force, 2008a, p. 41).
 - "The fundamental reason for creating any warfighting organisation is to provide the nation with an ability to apply force, sometimes lethal force, in support of its national interests" (Royal Australian Air Force, 2008b, p. 37).

The above statements provide context for why the Air Combat system, a primary lethal force capability for the ADF³⁰, requires the capacity for destruction. However, to determine the exact contribution destruction affords to air combat, and the implications for such a function, relevant Air Force and Defence publications were consulted.

- ❖ The raw data extracted from these publications suggest that the purpose-related function of destruction encapsulates those terms which broadly denote a loss of functionality and/or the ability for restoration. Specifically, when terms like 'nullify', 'obliterate', 'destruct', 'annihilate', 'damage', and 'destroy' are referred to in an air combat context, the destructive capacity of the Air Combat system is ultimately reflected:
 - "Defensive counter air comprises all measures designed to nullify or reduce the effectiveness of hostile air action" (Royal Australian Air Force, 2008b, p. 65).

²⁹ It is important to note that the term 'threat' within the air combat model refers to a "potential event or intention that could adversely affect the security of a facility, asset or function" (Department of Defence, 2012). As specific to the Air Combat system, this definition only refers to threats of a combative nature, for example those entities threatening an attack. This is distinct to the Air Power work domain analysis (a complementary analysis currently being developed by the Centre for Cognitive Work and Safety Analysis, DSTO) where 'threats' are conceptualised as the whole spectrum of events or intentions that may negatively affect the security of Australia from enemy attack through to natural disasters (see the functional purpose statement of Air Power for further information).

³⁰ The Air Combat system is considered a primary lethal force capability for the ADF as no other Australian airborne platform possesses a comparative destructive capacity (Royal Australian Air Force, 2008a, 2008b). In this sense, the Air Combat system significantly contributes to the lethality of the entire ADF (inclusive of Army, Navy, and Air Force).

- “Strategic attack is the precise application of air power in offensive operations to...destroy carefully chosen adversary targets” (Royal Australian Air Force, 2008b, p. 40).
- “... the commander attempts to annihilate the fleeing enemy force as the enemy becomes demoralized and cohesion and control disintegrate. Because the objective of the pursuit is destruction of the enemy, CAS [Close Air Support] can keep direct pressure on the enemy to prevent them from reorganizing or reconstituting” (North Atlantic Treaty Organisation [NATO], 2011, Chapter 2, p. 6).

The above statements provide context for how air combat destruction is captured within Air Force and Defence publications. Though not explicitly stated in the above excerpts, this destructive capability, as enabled by the Air Combat system’s kinetic weapons, is generally permanent in nature.

- ❖ An intrinsic aspect of air combat destruction is the ability to impact opposing forces physically and psychologically through the application of kinetic weaponry:
 - “...a psychological targeting effect is mostly dependent on some form of destruction” (Butler, 2008, p. 32).
 - “...effects [can] have both physical and psychological dimensions” (Smith, 2002, p. 106).
 - “Destruction is a means to an end and an enabler of psychological effects” (Butler, 2008, p. 32).

Though the primary intent may be to physically destroy an enemy entity, as the statements above suggest, the psychological implications of such a function can alter the future behaviour of an enemy entity (Deptula, 2001).

- ❖ The Air Combat system is required to respect domestic, international, and operational law/policy directives when applying lethal force. Specifically, the Australian Air Combat system is legally and ethically obligated to act in accordance with the principles of Law of Armed Conflict (LOAC) and Rules of Engagement (ROE) when using kinetic weapons to meet military objectives:
 - “The ADF prides itself on adhering to the rule of law” (Pender, 2004, p. 19).
 - “...it is clear that we are seeking the moral high ground – a force for good³¹” (Department of Defence, 2002, p. 1).
- ❖ The capacity to deploy weapons and destruct an entity facilitates the Air Combat system’s air patrol and air escort capabilities:
 - “The major ADF contribution to Coalition operations in southern Iraq was provided by 14 F/A-18 Hornets from 75 Squadron RAAF. Their initial role was to protect high-value Coalition aircraft such as air-to-air refuellers and intelligence collection aircraft. Such aircraft are important ‘force multipliers’ and their loss would have had a significant impact” (Australian Defence Force, n.d., p. 26).

As the above statements illustrate, the Air Combat system is capable of fulfilling a protective role (‘force protection’) for other, more vulnerable, defence assets, such as the Airborne Early Warning and Control (AEW&C) system, ground force personnel, and facilities. This role is solely enabled by the Air Combat system’s capacity for destruction.

Glossary:

- ❖ *Annihilate*: To reduce to nothing; destroy utterly (Macquarie Dictionary Online, 2012).

³¹ The Department of Defence’s *FORCE 2020* (2002) publication outlines the vision statement for the ADF as “a force for good – a force to be reckoned with – a force to win” (p. 1).

- ❖ *Destroy*: To reduce to pieces or to a useless form; to render ineffective (Macquarie Dictionary Online, 2012).
- ❖ *Destruct*: To blow up automatically; to destroy (a missile, etc.) (Macquarie Dictionary Online, 2012).
- ❖ *Domestic Law*: Domestic or municipal law encompasses those internal laws that govern the behaviour of persons within a state and in some cases may affect nationals abroad. An Act of Parliament, such as the *Defence Force Discipline Act 1982* (DFDA), is an example of a domestic law that binds Australian Service personnel within Australia and abroad. International law can also become part of a state's domestic law; the Australian Parliament's ratification of the 1977 Protocols Additional to the Geneva Conventions of 1949 (Additional Protocols) being just one example. In the absence of specific legislation, international law can still be regarded as part of domestic law; although certain legal conditions are required (Royal Australian Air Force, 2004a, p. 2).
- ❖ *Effect*: The adverse physical, physiological, psychological or functional impact on the enemy as a result, or consequence of, own military or non-military actions (Department of Defence, 2012).
- ❖ *Interdiction*: An action to divert, disrupt, delay, or destroy the enemy's military surface capability before it can be used effectively against friendly forces, or to otherwise achieve objectives (Department of Defence, 2012).
- ❖ *International Law*: Operations law is primarily a product of international law which is itself concerned with international law and order and security. While it defies precise definition, international law is equally applicable to individuals despite the fact that it governs relations between states. In international law the term 'states' refers to nations which are accepted as legitimate members of the international community (Royal Australian Air Force, 2004a, p. 1).
- ❖ *Kinetic*: Relating to motion; caused by motion (Macquarie Dictionary Online, 2012).
- ❖ *Law of Armed Conflict (LOAC)*: The international law regulating the conduct of States and combatants engaged in armed hostilities (Department of Defence, 2012).
- ❖ *Lethal*: The method of attack which is intended to cause physical damage to personnel, material or capabilities (Department of Defence, 2012).
- ❖ *Lethal weapon*: A weapon that can be used to cause death or serious bodily injury (Department of Defence, 2012).
- ❖ *Nullify*: To make ineffective, futile, or of no consequence (Macquarie Dictionary Online, 2012).
- ❖ *Obliterate*: To remove all traces of; do away with; destroy (Macquarie Dictionary Online, 2012).
- ❖ *Operations law*: Operations law is that domestic and international law associated with planning and execution of military operations in peacetime or during armed conflict. It includes but is not limited to LOAC, air law, law of the sea, anti- and counter-terrorist activities, overseas procurement, discipline, pre-deployment preparation, deployment, status of forces agreement, operations against hostile forces, aid to the civil authority, border protection and civil affairs operations (Royal Australian Air Force, 2004a, p. 2).
- ❖ *Rules of Engagement (ROE)*: Directives endorsed by Government and issued by commanders, which delineate the circumstances, and limitations within which military force may be applied to achieve military objectives (Department of Defence, 2012).
- ❖ *Weapon*: An offensive or defensive instrument of combat used to destroy, injure, defeat or threaten an enemy. Examples: gun, bomb, or bomber (Department of Defence, 2012).

DISABLEMENT

Definition of Disablement:

'Disablement' is defined as the ability of the Air Combat system to [disable](#) a specified [entity](#) from [achieving](#) its [goals](#) for as [long](#) as [necessary](#). Specifically, the Air Combat system must be capable of [interfering](#) with and/or [manipulating](#) an entity's electromagnetic devices when required.

[Disable:](#)

The Macquarie Dictionary Online (2012) defines the term 'disable' as "make unable", with the Collins Dictionary Online (2012) specifying it as "to make ineffective, unfit, or incapable". For the current analysis, disablement represents those capabilities which seek to [interfere](#) with and/or [manipulate](#) an entity's [effective use](#) of its electromagnetic devices. When correctly applied, these abilities can significantly inhibit hostile behaviour directed at the Air Combat system and the friendly forces with which it interacts. Active and passive countermeasures, such as jammers, flares and decoys, are presently³² employed to enable these outcomes.

- [Interfere/Interfering:](#)

One method of air combat disablement is to interfere with an entity's ability to access accurate information via its electromagnetic device/s. As defined by the Collins Dictionary Online (2012), 'interfere' is the action of "come[ing] between or in opposition; hinder; obstruct". For this aspect of air combat disablement to be attained, an entity must be obstructed from gaining unauthorised access to air combat or friendly force information. This could be achieved, for example, by jamming an enemy fighter jet's sensor systems so that information specific to friendly force movements and composition is actively withheld (US Air Force, 2002).

- [Manipulate/Manipulating:](#)

A further air combat disablement technique is that of manipulation. The Collins Dictionary Online (2012) defines the term 'manipulate' as "to falsify for one's own advantage". The Air Combat system must be capable of directing false and/or misleading information to an entity's electromagnetic device/s so as to deceive and confuse. This aspect of air combat disablement could be achieved, for example, by emitting signals which falsely produce targets on an enemy entity's radar scope (US Air Force, 2005, p. 11).

- [Effective use:](#)

'Effective' has been defined as "serving to effect the purpose; producing the intended or expected result" (Macquarie Dictionary Online, 2012), with 'use' described as "to employ for some purpose" (Macquarie Dictionary Online, 2012). For the function of air combat disablement to be achieved, the Air Combat system must compromise the performance of an entity's electromagnetic device/s so that it cannot be employed as intended. Within a military sphere, electromagnetic devices are utilised to support situational awareness, rapid communication, detection, and targeting.

[Entity:](#)

As defined by the Macquarie Dictionary Online (2012), an 'entity' is "something that has a real existence; a thing, especially when considered as independent of other things". Within the current analysis, an 'entity' is generally synonymous with a combat [target](#).

- [Target:](#)

The Department of Defence (2012) defines 'target' as "the object of a particular action, for example a geographic area, a complex, an installation, a force, equipment, an individual, a group or system". This broad definition captures an extensive number of physical objects, for example [personnel](#), [material](#), or [capabilities](#).

³² Within the Air Combat Capability model, the disablement function is primarily enabled by the countermeasures subsystem. At present, the countermeasures subsystem only consists of those technologies which are currently represented on an Australian air combat aircraft (e.g., chaff, flare, decoy). Inclusion of emerging disabling technologies will be considered in further iterations of the analysis.

- **Personnel:**

The term 'personnel' is described as "those individuals required in either military or civilian capacity to accomplish the assigned mission" (Department of Defence, 2012).

- **Material:**

'Material' has been described as "the substance or substances of which a thing is made or composed" (Macquarie Dictionary Online, 2012), with 'thing' defined as a "material object without life or consciousness" (Macquarie Dictionary Online, 2012). Based on the above definitions and sub-definitions, the current analysis will refer to 'material' as any object devoid of life/consciousness. This may include, for example, platforms (e.g., Sukhoi T-50) or facilities.

- **Capability:**

The term 'capability' has been defined by the ADF (Department of Defence, 2012) as "the power to achieve a desired operational effect in a nominated environment within a specified time and to sustain that effect for a designated period". This definition of 'capability' will be adopted within the current analysis to describe a target's capability.

Achieve/Achieving:

'Achieve' is described by the Macquarie Dictionary Online (2012) as "to bring to a successful end; carry through; accomplish". As specific to the purpose-related function of disablement, the above definition of achieve will be applied when describing those actions taken by a specified entity to attain a desired result.

Goals:

The Oxford Dictionary Online (2012) defines a 'goal' as "the object of a person's ambition or effort; an aim or desired result". For the current analysis, 'goals' refer to a desired result, or set of results, a specified entity (e.g., combat target) is tasked to attain. This could include, for example, destroying an opposition fighter jet or dismantling an entire opposition force.

Long:

The term 'long' has been defined by the Collins Dictionary Online (2012) as "having relatively great duration in time". The duration of time required for disabling an entity must be flexible, and potentially extensive, depending on the type of entity, desired effect, and operational requirements. The Air Combat system should consider these constraints when performing this function.

Necessary:

The Collins Dictionary Online (2012) describes the term 'necessary' as "needed to achieve a certain desired effect or result". By adopting this definition, the Air Combat system must be capable of disabling an entity for as long as required to ensure that it is no longer a threat.

Rationale and supporting documentation:

- ❖ Disablement is a purpose-related function for the Air Combat system. The Air Combat system must be capable of disabling a specified entity's ability to achieve its intended operational goals/mission plans through non-lethal means of action. Specifically, this function allows for a lessening of an entity's combat capability, whilst supporting friendly operational requirements, and without causing unnecessary suffering, injury, or destruction to the civilian population and its infrastructure:
 - "Non-lethal weapons have the potential to enhance the ADF mission by contributing to the basic goal of any military operation, which is the establishment of a stable and enduring peace after victory has been achieved" (Casagrande, 1995, p. 10).
 - "Australia is also party to many international treaties which place restriction of the use of military force. One of the most important principles underlying these obligations is the requirement to attack only legitimate military targets, using only such force as is necessary to achieve the military objective while attempting to minimise civilian injuries and damage. Any collateral damage or incidental injuries must be kept to a minimum

and proportional to the planned military objective. Non-lethal weapons will assist with compliance within these obligations” (Casagrande, 1995, p. 11).

- ❖ In order to better understand the specific contribution air combat affords to disablement, the fundamental concepts relating to this purpose-related function were explored through raw data analysis. First, it was determined that the RAAF and ADF use a number of different terms to illustrate non-lethal actions or outcomes directed at an entity, such as ‘delay’, ‘degrade’, ‘neutralise’, ‘disrupt’, ‘deceive’, ‘suppress’, ‘negate’, and ‘impede’:
 - “Defensive counter air comprises all measures to...*neutralise* the effectiveness of hostile air action and to prevent the enemy from gaining control of the air” (Royal Australian Air Force, 2008a, p. 142).
 - “Air interdiction is conducted to...*delay*...the opponent’s military potential before it can be brought to bear effectively against friendly forces” (Royal Australian Air Force, 2008a, p. 148).

Though these terms are distinct from each other at a definitional level (Department of Defence, 2012), they can all be captured under the umbrella term of disablement (see above for the air combat specific definition). That is, they all refer to non-lethal means of action to interfere with and manipulate an entity’s ability to meet its operational goals/mission plans.

- ❖ To achieve the purpose-related function of air combat disablement, the Air Combat system must be capable of disabling the effective use of an entity’s electromagnetic device/s. This function is particularly important given Defence Forces and their platforms are heavily reliant on electronic devices for reconnaissance and surveillance data, threat warning data, location and emitter identification data, and for accurate weapon directory in the current military climate (US Joint Defense Services, 2007):
 - “The synergistic effects of various EW [Electronic Warfare] techniques can significantly disrupt an IADS [Integrated Air Defence System], sensors, communication links, weapons systems, and C2 [Command and Control]. Jamming, chaff, and decoys degrade the enemy’s ability to find, fix, target, engage, and assess. Radar-guided weapon systems that survive destruction attempts lose some effectiveness in an EW environment” (US Air Force, 2002, p. 16).

The above statement suggests that by disabling an entity’s electromagnetic devices, the total effectiveness of that entity can be significantly impaired (US Air Force, 2002). By using means like noise jamming or electronic deception, which are inherently non-lethal in their approach, the Air Combat system can gain an advantage over a specified entity without inflicting irreversible damage.

To illustrate this point further, during the 2011 military intervention in Libya, air combat platforms (e.g., EA-18 Growler) were employed to interfere and abate the Libyan regime’s air and ground force sensors, communications, and weapons. Such actions were considered to be the primary enabler of establishing a no-fly zone and reducing the utility of the Libyan defences:

- “EA-18 Growler jets have been deployed to Libya. Instead of bombs, they carry an array of radars, antennas and high-tech gear to thwart enemy air-defense systems” (Hennigan, 2011).
- “[US Navy] pilots and crews will employ Growler’s systems not just to jam signals, but to control aspects of the electromagnetic spectrum to protect our troops and engage our enemies” (Mullen, 2011).
- “Each of the devices hanging from the Growler’s wings performs a different function, including pinpointing the location of enemy radar sites, intercepting and jamming radio signals and following the changing enemy radar tactics” (Hennigan, 2011).

- “The RAAF may soon have 12 of its Super Hornet fighter-bombers equipped as ‘Growlers’, the US aircraft packed with electronic equipment that paralysed the Libyan regime’s communications and missile systems” (Nicholson, 2011).

Through the application of non-lethal, disabling methods, the Growler platform demonstrated its capacity for supporting NATO forces in accomplishing their operational requirements. Specifically, by performing air combat disablement, total control of the electromagnetic spectrum was obtained for friendly forces. Within an Australian context, air combat disablement will be further strengthened with the future addition of the Growler technology.

- ❖ Air combat disablement is achieved through two primary capabilities, specifically interference and manipulation. As defined above, interference concerns denying an entity’s electromagnetic device access to accurate information. To achieve this end, the Air Combat system must be capable of applying traditional jamming techniques (i.e., spot, sweep, etc.) and expending aerial countermeasures for unauthorised information to be blocked:
 - “Denial is controlling the information an enemy receives via the electromagnetic spectrum and preventing the acquisition of accurate information about friendly forces” (US Army Headquarters, 2009, Chapter 1, p. 11).
 - “The effective application of electronic warfare in support of mission objectives is critical to the ability to find, fix, track, engage, and assess the adversary, while denying that adversary the same ability” (US Air Force, 2002, Chapter 2, p. 5).
- ❖ A further capability of air combat disablement is that of manipulation. Manipulation refers to those actions which seek to provide false and/or misleading information to an entity’s electromagnetic device, and, in so doing, compromising the performance of that device:
 - “The goal is to mislead the enemy by manipulating his perceptions in order to degrade the accuracy of his intelligence and target acquisition” (Anderson, 2008, Chapter 16, p. 322).
 - “From use of the electromagnetic spectrum, EW deception manipulates the enemy’s decision loop, making it difficult to establish accurate situational awareness” (US Army Headquarters, 2009, Chapter 1, p. 11).
 - “Military deception misleads or manages the perception of adversaries, causing them to act in accordance with friendly objectives” (US Air Force, 2005, p. 11).

As the above statements demonstrate, the capacity to provide purposively false and/or misleading information can be hugely beneficial to the Air Combat system and its friendly forces. Specifically, when friendly force information is manipulated and directed to opposing forces, the capacity of those forces to plan effective countermeasures is greatly reduced.

Glossary:

- ❖ *Active*: In surveillance, an adjective applied to actions or equipments which emit energy capable of being detected (Department of Defence, 2012).
- ❖ *Chaff*: Strips of frequency-cut metal foil, wire, or metalised glass fibre used to reflect electromagnetic energy, usually dropped from aircraft or expelled from shells or rockets as a radar countermeasure (Department of Defence, 2012).
- ❖ *Countermeasure*: An action or device designed to negate or offset another (Merriam-Webster Dictionary Online, 2012).
- ❖ *Decoy*: An imitation of a person, object or phenomenon, which is intended to deceive hostile surveillance or detection systems or mislead the adversary (Department of Defence, 2012).
- ❖ *Device*: A thing made or adapted for a particular purpose, especially a piece of mechanical or electronic equipment (Oxford Dictionary Online, 2012).
- ❖ *Disruption*: A direct attack that neutralises or selectively destroys key elements of the enemy’s capabilities. The aim of disruption is to reduce the enemy’s cohesion and will to fight by

neutralizing or destroying parts of its force in a manner that prevents the force from acting as a coordinated whole (Department of Defence, 2012).

- ❖ *Electromagnetic interference*: Any electromagnetic disturbance, whether intentional or not, which interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic or electrical equipment (Department of Defence, 2012).
- ❖ *Electromagnetic spectrum (EMS)*: That range of frequencies in which oscillating electric and magnetic fields propagate waves at the speed of light. This includes cosmic and gamma radiation, X-rays, ultraviolet, visible and infra-red radiation and radio waves (Department of Defence, 2012).
- ❖ *Electronic attack*: Division of electronic warfare involving the use of electromagnetic energy, directed energy, or antiradiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralising, or destroying enemy combat capability and is considered a form of fires (Department of Defence, 2012).
- ❖ *Electronic warfare*: Military action involving the use of electromagnetic and directed energy to determine, exploit, reduce or prevent hostile use of, and retain friendly use of, the electromagnetic spectrum (Department of Defence, 2012).
- ❖ *False*: Not true or correct (Macquarie Dictionary Online, 2012).
- ❖ *Jammer*: A device which interferes with radio signals, as in blocking radar, mobile phones, etc. (Macquarie Dictionary Online, 2012).
- ❖ *Jamming*:
 1. To interfere with (signals, etc.) by sending out others of approximately the same frequency (Macquarie Dictionary Online, 2012).
 2. Deliberate interference, caused by emissions intended to render unintelligible or falsify the whole or part of a wanted signal (Department of Defence, 2012).
- ❖ *Neutralise*: A tactical task to render an enemy element temporarily incapable of interfering with the operation (Department of Defence, 2012).
- ❖ *Non-lethal*: Not resulting in or capable of causing death (Collins Dictionary Online, 2012).
- ❖ *Passive*: In surveillance, an adjective applied to actions or equipments which emit no energy capable of being detected (Department of Defence, 2012).
- ❖ *Passive electronic protective measures*: Undetectable measures, such as those in operating procedures and technical features of equipment, to ensure effective friendly use of the electromagnetic spectrum (Department of Defence, 2012).
- ❖ *Soft kill*: Efforts using other than explosive or kinetic systems to destroy or neutralise a target. They may include electronic measures (Department of Defence, 2012).

INFORMATION COLLECTION AND DISSEMINATION

Definition of Information Collection and Dissemination:

'Information collection and dissemination' is defined as the ability of the Air Combat system to [collect](#) and [disseminate information](#) related to its environment or a specified [entity](#). This function is supported by the Air Combat system's capacity to access unique forms of information in high threat, complex areas of operation (i.e., aerial warfare, flying over denied areas).

[Collect:](#)

The Collins Dictionary Online (2012) defines 'collect' as "to gather together or be gathered together". Within the context of this purpose-related function, the Air Combat system must be capable of gathering information to achieve its functional purpose statement, and to support friendly forces in reaching their mission objectives. By utilising the sensor subsystem and its components (e.g., radar, infra-red), information pertaining to an entity's location or general environmental characteristics, for example, can be collected.

[Disseminate:](#)

The concept of 'disseminate' is described as to "spread (something, especially information) widely" (Oxford Dictionary Online, 2012) or "to distribute or scatter about; diffuse" (Collins Dictionary Online, 2012). For air combat, dissemination refers to the ability of the Air Combat system to distribute information to the relevant agencies/networks for effective decisions to be made (Royal Australian Air Force, 2011, Chapter 5, p. 20). This capability is principally achieved via the communication subsystem's components (e.g., Link 16, VHF radio).

[Information:](#)

The Royal Australian Air Force (2008b, p. 66) defines 'information' as "unprocessed data of every description which may be used in the production of intelligence". Specific to this purpose-related function, 'information' can refer to an entity's [presence](#), [location](#), [classification](#), [identity](#), [capabilities/limitations](#) and [intentions](#), and the [environmental characteristics](#) of a particular area (Royal Australian Air Force, 2008a, 2008b).

- [Presence:](#)

The concept of 'presence' is defined as "the state or fact of being present" (Macquarie Dictionary Online, 2012), with 'present' described as "being in a specified place" (Collins Dictionary Online, 2012). By adopting the above definitions, presence within the current analysis will refer to the ability of the Air Combat system to detect the general existence of a specified entity (i.e., air or surface combat target).

- [Location:](#)

The ability to 'locate' is described as "to set, fix, or establish in a place, situation, or locality" (Macquarie Dictionary Online, 2012), with 'location' defined as a "place or situation occupied" (Macquarie Dictionary Online, 2012). For the present analysis, the ability to determine the exact location of a moving entity (i.e., air or surface combat target) results in two primary outcomes. Firstly, it provides a sound foundation from which additional information relating to a specific entity (e.g., classification, identity) can be collected, and secondly, this capability provides support for other capability requirements, such as destruction or disablement (i.e., to achieve accurate physical destruction or disablement of an entity, its location must be correctly established).

It is important to highlight that the ability to determine the 'location' of a specified entity is distinct from determining presence, insofar as the concept of 'presence' refers to the general existence of an entity as opposed to determining its precise locale. As such, presence could be considered a first step in establishing an entity's location.

- [Classification:](#)

The act of classifying something is defined as being "to arrange or distribute in classes" (Macquarie Dictionary Online, 2012). For the current analysis, the Air Combat system must be

capable of establishing the category/class to which an entity belongs to (e.g., fighter or civilian aircraft; friendly, hostile, or unknown entity) so as to effectively meet the functional purpose of air combat (Lee, 2005).

- **Identity:**

The term 'identity' has been described as the "individual characteristics by which a person or thing is recognised" (Collins Dictionary Online, 2012). Within an air combat context, the Air Combat system must be capable of distinguishing a specified entity based on its individual characteristics (e.g., F-22 from a Su-27). By establishing the identity of an entity, an additional layer of information from that collected at the classification level can occur.

- **Capabilities/ Limitations:**

The Oxford Dictionary Online (2012) defines 'capabilities' as "the power or ability to do something". Based on this definition, a set of capabilities are considered to be those individual abilities or characteristics which enable an entity to achieve its desired outcomes or effects. For example, an enemy fighter jet's capabilities could be measured according to its maximum speed or precise targeting. Such capabilities, if utilised correctly, may facilitate that fighter jet achieving its mission, task, or function.

In contrast to capabilities, the concept of 'limitation[s]' has been defined as "a restriction or controlling of quantity, quality, or achievement" (Collins Dictionary Online, 2012). For the current analysis, an entity's limitations will be defined as any restricting/limiting factor (e.g., payload weight) which interferes with its ability to achieve desired outcomes or effects.

- **Intentions:**

The Department of Defence (2012) defines 'intention' as "an aim or design (as distinct from capability) to execute a specified course of action". From an air combat perspective, information pertaining to an entity's intentions may concern what course of action the entity is likely to take and how the entity will react to attack/defensive actions.

- **Environmental characteristics:**

The term 'environmental' is defined as "external conditions or surroundings" (Collins Dictionary Online, 2012), with 'characteristics' described as "a distinguishing quality, attribute, or trait" (Collins Dictionary Online, 2012). As distinct from collecting entity specific information, this purpose-related function also requires the Air Combat system to be capable of gathering information relating to the external conditions in which it operates. This could include, for example, information relating to terrain (e.g., hydrological data, elevation data), weather (e.g., visibility, wind), and climate (e.g., long-term averages of daily weather) (National Aeronautics and Space Administration [NASA], 2005; US Army Headquarters/US Marine Corps Headquarters, 2009). Collection of this type of information can support the development of a common tactical picture of the operational environment.

Entity:

As defined by the Macquarie Dictionary Online (2012), an 'entity' is "something that has a real existence; a thing, especially when considered as independent of other things". Within the current analysis, an 'entity' is generally synonymous with a combat [target](#).

- **Target:**

The Department of Defence (2012) defines 'target' as "the object of a particular action, for example a geographic area, a complex, an installation, a force, equipment, an individual, a group or system". This broad definition captures an extensive number of physical objects, for example [personnel](#), [material](#), or [capabilities](#).

- **Personnel:**

The term 'personnel' is described as "those individuals required in either military or civilian capacity to accomplish the assigned mission" (Department of Defence, 2012).

- **Material:**

'Material' has been described as "the substance or substances of which a thing is made or composed" (Macquarie Dictionary Online, 2012), with 'thing' defined as a "material

object without life or consciousness" (Macquarie Dictionary Online, 2012). Based on the above definitions and sub-definitions, the current analysis will refer to 'material' as any object devoid of life/consciousness. This may include, for example, platforms (e.g., Sukhoi T-50) or facilities.

- **Capability:**

The Oxford Dictionary Online (2012) defines 'capability' as "the power or ability to do something". Based on this definition, a capability is considered to be those abilities or characteristics which enable an entity to achieve its desired outcomes or effects. For example, a target's capabilities may refer to its capacity for flight as required by an enemy fighter jet, or the capacity for real time information to be exchanged as required by a command and control centre.

Environment:

The term 'environment' is described as "the surroundings or conditions in which a person, animal, or plant lives or operates" (Oxford Dictionary Online, 2012). In the context of the current analysis, the environment refers to those surroundings or conditions in which the Air Combat system operates, specifically in the air and on land.

Rationale and supporting documentation:

- ❖ Information collection and dissemination is a purpose-related function of the Air Combat system. The Air Combat system must be capable of collecting and disseminating information, as related to its environment or a specified entity, for its functional purpose to be achieved. As applied within a military context, this dual function can have wide reaching, positive implications for the Air Combat system and the friendly forces with which it interacts:

- "There is no doubt that advanced information and communication technologies and the capabilities that they impart will significantly change the nature of military roles, missions, and methods" (Alberts & Papp, 2001, p. 1).
- "Air Force ISR can integrate cross-domain data from Air Force airborne and ground-based assets...The subsequent information and intelligence derived from such data can be exploited by RAAF, other ADF, joint and allied forces" (Royal Australian Air Force, 2011, Chapter 2, p. 20).

As these statements attest, information can play a pivotal role in achieving overall operational success. Through access to information, enhanced decision making and improved situation awareness can materialise, which in turn can minimise the likelihood of casualties and material losses, and provide greater accuracy and timeliness for destructive and disabling functions (Australian Defence Force, 2006, Chapter 1, p. 8-9; Royal Australian Air Force, 2011, Chapter 4, p. 14).

- ❖ Air combat aircraft are generally categorised as a 'non-traditional' form of Intelligence, Surveillance, and Reconnaissance (ISR) (Williams, 2007). Non-traditional, in this sense, refers to those capabilities that, while not primarily intended to support ISR missions, can provide vital information for friendly force operations (US Air Force, 2007, p. 6). As specific to an air combat aircraft, given its particularly advanced sensor components (e.g., infra-red, radar), and the unique locations in which it operates, such aircraft remain an enabler of ISR across the battlespace (Deptula, 2009):
 - "Fighter and bomber aircraft, by design, have operational access to areas of the battlespace that are denied to traditional ISR aircraft. Furthermore, some sensors onboard fighters and bombers are designed for targeting weapons and can provide greater resolution than many standoff ISR sensors" (US Air Force, 2007, p. 7).
 - "Available collection resources are not limited to platforms or sensors that were specifically designed to collect intelligence. With the increasing sophistication of airborne sensors, many, if not all, aircraft can conduct reconnaissance or surveillance

to varying degrees, even if intelligence collection is not their primary mission" (Air Warfare Centre, n.d., Chapter 2, p. 8).

- "The fact that it [F-22] can negate adversary anti-access capabilities, and can operate in denied airspace unconstrained, means we can make use of its ISR capabilities that otherwise would not be available without enormous cost in alternate means" (Deptula, 2001, p. 43).
- ❖ For the current analysis, the Australian Air Combat system must be capable of performing the dual function of information collection and information dissemination. Based on raw data extracted from RAAF and ADF publications, it is clear that Australia's Air Combat system has previously been utilised (F-111C) and is currently contributing (F/A-18A/B, F/A-18F) to ISR-based activities. This function is expected to continue into the future with the introduction of the Joint Strike Fighter (JSF; F-35A):
 - "The F-35 Lightning II Joint Strike Fighter will bring to the RAAF not only a significant air combat capability, but also a very significant ISR capability that will span many ISR collection disciplines" (Royal Australian Air Force, 2011, Chapter 8, p. 6).
 - "Fast jet combat aircraft such as the F/A-18F Super Hornet provide the ADF with a capability to penetrate the battlespace against opposition and permeate adversary targets with multiple ISR collection disciplines. A pervasive ISR capability requires sensors that can perform throughout the electromagnetic spectrum across the physical domains and defeat adversary counter detection techniques" (Royal Australian Air Force, 2011, Chapter 2, p. 19).
 - "The F-35 Joint Strike Fighter will be three times more effective than legacy fighters in non-traditional Intelligence Surveillance Reconnaissance (ISR)" (Global Security.org, 2012).

The above statements recognise that Australia's Air Combat system contributes to RAAF and ADF ISR³³ activities respectively. However, to determine the exact input air combat affords to this area, a detailed analysis of the relevant literature was undertaken.

- ❖ The Air Combat system requires the capacity to collect information of potential military significance for the current purpose-related function to be attained. This function is predominately enabled by the inbuilt, and highly advanced, sensor components readily found on an air combat aircraft:
 - "The APG-79 [employed on the F/A-18F] active electronically scanned array (AESA) radar provides significantly more capability for threat detection and precise identification and location accuracy" (Williams, 2007, p. 11).
 - "Air Force forces operating through the battlespace have a wide range of sensors to support navigation, environmental data collection, threat warning, and target acquisition. Many of these systems are used for onboard situational awareness and weapons employment, but the information they collect can also have a great value to other elements of the joint force" (US Air Force, 2007, p. 7).
 - "The JSF will be fitted with an advanced Electro-Optical Targeting System (EOTS) that provides long range infra-red search and track of air targets, long range detection of

³³ 'ISR', the abbreviation for Intelligence, Surveillance and Reconnaissance, is defined by the Department of Defence (Version 6.2.0, ADF Joint definition) as "a collection activity that synchronises and integrates the acquisition, processing and provision of information and single source intelligence by sources and agencies tasked to satisfy a collection requirement". The Air Combat system is capable of performing a surveillance and reconnaissance function within the RAAF/ADF. Specifically, the Air Combat system contributes to surveillance by having the capacity to detect and observe targets (e.g., environmental characteristics, enemy platforms) at an extended distance from a target (i.e., beyond visual range) (Moir & Seabridge, 2006, p. 9), and in airspace which is generally inaccessible to traditional ISR assets (i.e., AEW&C, AP-3C) (US Air Force, 2007, p. 7; Williams, 2007, p. 9). In terms of supporting reconnaissance activities, the Air Combat system has the capacity to collect precise information relating to a specified entity. 'Precise' information within this framework can refer to an entity's location, classification, identity, capabilities/limitations, and intentions.

ground targets, a laser range finder and a laser target designator" (Houston, 2004, p. 4).

As the above statements emphasise, the Air Combat system uses its sensor systems to collect information. Such information may be high-resolution imagery or electronic data, and be related to a specified entity (e.g., location, capabilities) or to specific environmental conditions (e.g., terrain, air visibility). Collection of this type of information lends itself to supporting the development of a common tactical picture, which in turn leads to greater situational awareness for friendly forces (Borgu, 2004).

- ❖ A second aspect of this purpose-related function concerns the ability to disseminate information. For the Air Combat system, this principally concerns the use of communication components, like radio and data links, which transmit information to decision makers and analysts (Williams, 2007, p. 5):

- "The JSF has an extensive communications and data link suite. The high capacity inter/intra flight data link allows a flight of JSFs to act as a fully fused team. Link 16 allows sharing of data with other air and surface players. Satellite communications provide for beyond line-of-sight communications (JSF is the first fighter aircraft to have satellite transmit and receive capability)" (Houston, 2004, p. 4).
- "Their [F-22 and F-35A] ability to distribute information at high speed enabled them to provide advance surveillance" (Defense Industry Daily, 2005).

These statements suggest that the communication subsystem enables the dissemination capability of this purpose-related function. This capability, in turn, allows for a networked, interoperable Air Force to be obtained, consequently enhancing decision making processes.

- ❖ An inherent aspect of this air combat function is the need for accurate, efficient, and timely information, whether it be at the collection or dissemination phase:

- "The Contemporary Operating Environment (COE) demands joint, inter-agency and multinational interoperability in all activities, including ISR. Furthermore, there is an ever increasing value on timely and accurate information" (Air Warfare Centre, n.d., Foreword, p. iv).
- "Precise weapons require accurate intelligence and, as such, ISR is of paramount importance to air power because it provides the backbone for the successful application of air power and directly enables the air campaign planning process" (Royal Australian Air Force, 2011, Chapter 2, p. 11).
- "The requirement for ISR generally exceeds the number of systems available to any given commander. As such ISR assets are invariably classified as high demand/low density assets and it is essential that the information gathered and exploited by them is effectively and efficiently disseminated and made available for use by all who require the product" (Air Warfare Centre, n.d., Chapter 1, p. 2).

As clearly stipulated in the above statements, information must be of an accurate, efficient, and timely nature for it to be useful to friendly force operations and the other functions the Air Combat system must perform (e.g., destruction, disablement, piloting).

- ❖ As this paper previously eluded to, an important point to note concerns the unique capacity of the Air Combat system to access information in high threat and complex environments (e.g., aerial warfare) and in denied areas (e.g., overhead flying). This capability is generally not afforded to other airborne platforms:

- "In recent years, ISR has been largely employed in benign areas with significant freedom of manoeuvre. There is a need for current and future defence forces to have ISR capability that can operate in and over denied areas or in high threat environments" (Royal Australian Air Force, 2011, Chapter 8, p. 5-6).

Access to otherwise unknown information allows the Air Combat system to support wider defence operations through the development of a generalised representation of battlespace, and can additionally facilitate in attaining the 'surprise' factor over a combat entity.

Glossary:

- ❖ *Battlespace*: The environment, factors and conditions that must be understood to successfully apply combat power, protect the force or complete the mission. This includes the air, land, sea, space environment; the included enemy and friendly forces; facilities; weather; terrain; the electromagnetic spectrum; and the information environment within the operational area and areas of interest (Department of Defence, 2012).
- ❖ *Common tactical picture*: A display of information from the common tactical dataset and other sources, which is the current depiction of the battlespace for a single operation within a specified area and includes current, anticipated or projected, and planned disposition of hostile, neutral, and friendly forces (Department of Defence, 2012).
- ❖ *Data*: Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means. Any representations such as characters or analog qualities to which meaning is or might be assigned (Department of Defence, 2012).
- ❖ *Detection*: The discovery by any means of the presence of a person, object or phenomenon of potential military significance (Department of Defence, 2012).
- ❖ *Dissemination*: The timely conveyance of intelligence, in an appropriate form and by any suitable means, to those who need it (Department of Defence, 2012).
- ❖ *Intelligence*: The product resulting from the processing of information concerning foreign nations, hostile or potentially hostile forces or elements, or areas of actual or potential operations. The term is also applied to the activity which results in the product and to the organisations engaged in such activity (Department of Defence, 2012).
- ❖ *Operational environment*: A composite of the conditions, circumstances and influences that affect the employment of capabilities and bear on the decisions of the commander (Department of Defence, 2012).
- ❖ *Reconnaissance*: A mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy, or to secure data concerning the meteorological, hydrographic, or geographic characteristics of a particular area (Department of Defence, 2012).
- ❖ *Surprise*: To assail, attack, or capture suddenly or without warning, as an army, fort, or person that is unprepared (Macquarie Dictionary Online, 2012).
- ❖ *Surveillance*: The systematic observation of aerospace, surface or sub-surface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means (Department of Defence, 2012).
- ❖ *Vulnerability*: The susceptibility of a nation or military force to any action by any means through which its war potential or combat effectiveness may be reduced or its will to fight diminished (Department of Defence, 2012).

SELF PROTECTION

Definition of Self Protection:

'Self protection', within an air combat context, is defined as the ability of the Air Combat system to [protect](#) itself from [external dangers](#). Specifically, to ensure ongoing air combat power, the Air Combat system must be capable of detecting those [entities](#) which aim to cause [harm](#) or [destruction](#) to the aerial system (e.g., ballistic missile, enemy aircraft).

[Protect:](#)

The Macquarie Dictionary Online (2012) defines the term 'protect' as "defend or guard from attack, invasion, annoyance, insult" or "keep safe from harm or injury" (Oxford Dictionary Online, 2012), with the Department of Defence (2012) describing 'protect' as a "tactical task to provide safety for an individual, group or force and prevent any loss as a result of enemy or other action". In these definitions, the act of protecting describes the prevention of harm, injury, or loss, subsequently enhancing the likelihood of survivability. For the current analysis, the Air Combat system must be capable of protecting itself, as inclusive of its human and material resources, against external dangers, at all times and in all conditions. This function is captured by the Air Combat system's ability for threat detection, such that advanced warning cues are provided to the aircrew and relevant information agencies.

[External:](#)

The Oxford Dictionary Online (2012) defines 'external' as "coming or derived from a source outside the subject affected". For the purposes of the current analysis, the term 'external' has been used to denote those dangerous entities which originate outside of the Air Combat system's control, such as an enemy fighter jet.

[Dangers/Danger:](#)

'Danger' is described as the "state of being vulnerable to injury, loss, or evil" (Collins Dictionary Online, 2012). For the purposes of the current analysis, the concept of danger/dangers encompasses those adverse outcomes, such as [harm](#) and [destruction](#), which affect the functionality of the Air Combat system, as inclusive of its [human](#) and [material resources](#).

- [Harm:](#)

The Macquarie Dictionary Online (2012) defines 'harm' as "injury; damage; hurt", with the Oxford Dictionary Online (2012) defining it as "physical injury, especially that which is deliberately inflicted". As specific to the Air Combat system, the concept of harm captures non-fatal consequences, such as physical hurt or intermittent damage.

- [Destruction:](#)

'Destruction', as defined within the Air Combat Capability analysis, is to destroy a specified entity beyond functionality or restoration. As applied to self protection, the concept of destruction denotes those fatal, ongoing outcomes directed at the human and material resources of air combat.

- [Human resources:](#)

The concept of 'human resources' is described as "the human component of an organisation, institution, business, country" (Macquarie Dictionary Online, 2012). For air combat self protection, the human component of the Air Combat system is the aircrew³⁴. As specific to the current analysis, the aircrew of the Air Combat system encompasses the air combat pilots and air combat officers (navigators).

- [Material resources:](#)

'Material' has been defined as "the substance or substances of which a thing is made or composed" (Macquarie Dictionary Online, 2012), with 'resources' described as "a source of supply, support, or aid" (Macquarie Dictionary Online, 2012). For the current analysis,

³⁴ The concept of 'aircrew' has been defined as "persons operating an aircraft in flight" (Macquarie Dictionary Online, 2012).

material resources will refer to any object which is devoid of life/consciousness. As specific to the Air Combat aerial system (airborne air combat aircraft³⁵), this would include its subsystems (e.g., navigation subsystem) and components (e.g., radar).

Entities/Entity:

As defined by the Macquarie Dictionary Online (2012), an 'entity' is "something that has a real existence; a thing, especially when considered as independent of other things". Within the current analysis, an 'entity' is synonymous with a combat target:

- Target:

The Department of Defence (2012) defines 'target' as "the object of a particular action, for example a geographic area, a complex, an installation, a force, equipment, an individual, a group or system". This broad definition captures an extensive number of physical objects, for example personnel, material, or capabilities.

- Personnel:

The term 'personnel' is described as "those individuals required in either military or civilian capacity to accomplish the assigned mission" (Department of Defence, 2012).

- Material:

The term 'material' has been defined above. When used in relation to a target, it encompasses platforms (e.g., Sukhoi T-50) and facilities (e.g., command and control centres).

- Capability:

The Oxford Dictionary Online (2012) defines 'capability' as "the power or ability to do something". Based on this definition, a capability is considered to be those abilities or characteristics which enable a target to achieve its desired outcomes or effects. For example, a target's capabilities may refer to its capacity for destruction as possessed by an enemy fighter jet, or the capacity for real time information to be exchanged as necessary for a command and control centre.

Rationale and supporting documentation:

- ❖ Self protection is a purpose-related function of the Air Combat system. The system must have the capacity to protect itself, including all human and material resources, against external dangers to achieve its functional purpose. This function ensures the ongoing preservation of air combat power through the ability to withstand hostile environments, and avoid degradation where possible:
 - "For air platforms, lack of effective self-protection can make the air vehicle undeployable due to its vulnerability, placing a premium on ensuring that air vehicles are acquired with self-protection systems and that those systems are upgraded to keep pace with emerging threats throughout an air vehicle's service life. All Air Force assets must be able to be protected by design, either because they have some organic ability to protect themselves or they come under the protection of another system" (Royal Australian Air Force, 2008b, p. 36).
 - "The ultimate aim of aviation safety within the ADF is the preservation of human and material resources to generate combat capability in all ADF aviation operations" (Australian Defence Force, 2009, p. 87).
 - "To protect these vital, and often scarce, platforms, aircraft design frequently includes self-protection systems and redundancy to reduce vulnerability and increase the

³⁵ The term 'aircraft' has been defined as "any machine supported for flight in the air by buoyancy or by dynamic action of air on its surfaces" (Macquarie Dictionary Online, 2012). Based on this definition of aircraft, an 'air combat aircraft' will be described as any aircraft which is capable of performing an airborne combat function in accordance with the Air Combat Capability functional purpose.

survivability of aircraft in complex hostile environments that contain highly-capable anti-aircraft weapons" (Royal Australian Air Force, 2008a, p. 97).

- ❖ To better understand the role of self protection within the Air Combat Capability analysis, the fundamental concepts relating to this purpose-related function were explored through raw data analysis. From this process it was first determined that the Air Combat system requires a significant level of protection. The level of protection needed is a direct function of the environment in which the system operates and the degree of expense associated with the system's demise:
 - "The high-threat environments in which air and space platforms operate place stringent demands on their design, maintenance and self-protection measures" (Royal Australian Air Force, 2008a, p. 97).
 - "Modern air forces can scarcely afford to suffer anything greater than a low incidence of losses, in both personnel and material, and there are inherent lethal risks involved to aircrew in the pursuit of the physical destruction of an adversary" (Butler, 2008, p. 23-24).

These statements demonstrate the importance of protection in facilitating the ongoing survivability of Australia's Air Combat system. To ensure Air Combat Capability is not compromised, the Air Combat system must be able to detect those threats which have the capacity and intent for harm and destruction.

- ❖ Raw data also highlights the interrelationship between self protection and the concept of force protection. 'Force protection', as defined by the RAAF, captures "all measures and means to minimise the vulnerability of personnel, facilities, equipment and operations to any threat and in all situations, to preserve freedom of action and the operational effectiveness of the force" (Department of Defence, 2012; Royal Australian Air Force, 2008a). As this definition suggests, force protection encompasses all protective measures taken across the entire force³⁶ in the avoidance of threats. This is distinct to the current analysis which posits self protection to be a function solely concerned with maintaining and enhancing the survivability of air combat. Additionally, this purpose-related function is only capable of protecting the Air Combat system from external, intent driven dangers (e.g., enemy action), as opposed to the total spectrum of threats (i.e., natural disasters through to combat) which the entire Air Force must be capable of protecting and mitigating against:
 - "Force protection (FP) seeks to minimise the vulnerability of both deployed and home-based personnel, facilities, material, information and operations to the threat posed by either an adversary or the environment, while preserving our freedom of action and operational effectiveness. FP affects every other warfighting function, because no operation can be raised, conducted or sustained from a vulnerable foundation" (Royal Australian Air Force, 2008b, p. 36).
- ❖ As noted previously, the Air Combat system operates in extremely dangerous environments. The origin of such danger is characterised by external, intent driven entities which seek to harm and/or destroy air combat power:
 - "Protection against future ballistic missile threats is something that the Air Force will need to consider with other Services and our allies" (Royal Australian Air Force, 2008b, p. 36-37).
 - "Potential adversary air and missile threats continue to grow in numbers and capabilities. Expanded technology and proliferation of missiles, including cruise missiles, ballistic missiles, and air-to-surface missiles, expand the scope and complexity of protecting friendly forces and vital interests" (US Joint Defense Services, 2012, Chapter 1, p. 6).

³⁶ The Department of Defence (Version 6.2.0, US Joint definition) defines 'force' as "an aggregation of military personnel, weapon systems, equipment, and necessary support, or combination thereof". Based on this definition, the RAAF and the ADF would be considered forces.

As the statements above demonstrate, danger can manifest itself in a variety of forms within the air combat sphere. Specifically, weapons (e.g., missiles, bombs) and enemy platforms (e.g., Sukhoi T-50) are considered to be the primary threats of the Air Combat system. However, as stated above, danger not only manifests itself in the physical domain (e.g., missile connecting with the Air Combat system), but is also evident in the non-physical, electromagnetic domain (e.g., disablement of the communication and sensor subsystem causing harm). Specifically, for the current purpose-related function to be attained, the Air Combat system must be capable of protecting itself against all external and intentionally driven danger entities.

- ❖ To effectively protect air combat power from external dangers, the Air Combat system must be capable of detecting those entities which seek to cause harm and/or destruction. Use of various threat warning components, like the radar warning receiver (RWR) and missile warning receiver (MWR), ensure the Air Combat system is aware, to the best of its knowledge, of potential dangers in the operational environment:
 - "...threat warning alerts are essential to the preservation of life and/or vital resources and such information should be immediately communicated directly to and acknowledged by those forces, platforms, or personnel identified at risk so the appropriate action can be taken" (Royal Australian Air Force, 2011, Chapter 5, p. 23).
 - "Relevant time sensitive information resulting from this step [Processing Phase] in the process (especially targeting, personnel recovery, or threat warning information) should be immediately disseminated to appropriate users" (Royal Australian Air Force, 2011, Chapter 5, p. 12).

To afford the self protection function, the Air Combat system must be capable of detecting and warning of the presence of a dangerous entity when operating within the battlespace. The Air Combat system must be proficient in these functional processes prior to engaging, avoiding, or evading any such entity.

Glossary:

- ❖ *Air Force Safety*: This is the management of the health and safety of all people in Air Force workplaces in the air and on the ground with an aim of keeping them free of injury or disease (Royal Australian Air Force, 2004b, p. 11).
- ❖ *Battlespace*: All aspects of air, surface, and subsurface, land, space, and the electromagnetic spectrum that encompass the area of influence and area of operations (Department of Defence, 2012).
- ❖ *Electronic protection*: That division of electronic warfare involving actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy use of the electromagnetic spectrum that degrade, neutralise, or destroy friendly combat capability (Department of Defence, 2012).
- ❖ *Fatal*: Causing death; causing destruction or ruin (Macquarie Dictionary Online, 2012).
- ❖ *Intent*: Something that is intended; aim; purpose; design (Collins Dictionary Online, 2012).
- ❖ *Survivability (system)*: The capability of a system to avoid or withstand a hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission (Department of Defence, 2012).
- ❖ *Vulnerability*: The characteristics of a system that cause it to suffer a definite degradation (incapability to perform the designated mission) as a result of having been subjected to a certain level of effects in an unnatural (man-made) hostile environment (Department of Defence, 2012).

PILOTING

Definition of Piloting:

'Piloting' is defined as the ability of the Air Combat system to [move](#) as [directed](#), through the [air](#) and on the [ground](#), in relation to a [preferred route](#). This function enables the Air Combat system the capacity to manoeuvre within the operational environment.

Move/Movement:

The Collins Dictionary Online (2012) has defined the term 'move' as "to go or take from one place to another, change in location or position". As applied to air combat piloting, the Air Combat system must be physically capable of altering its location or position, on the ground and in the air, to support its functional purpose statement. This aspect of piloting is principally afforded by the air vehicle subsystem (e.g., propulsion system).

Direct/Directed:

The term 'direct[ed]' has been described as to "regulate the course of" (Macquarie Dictionary Online, 2012) and to "control the operations of" (Oxford Dictionary Online, 2012). For the current analysis, the Air Combat system must be capable of regulating the course of its movement where required. This is facilitated by the mission control subsystem (e.g., flight control system), which allows the aircrew to manipulate aircraft movement, and the navigation subsystem (e.g., GPS³⁷, INS³⁸), which enables calculated movement of the aircraft to occur.

Air:

The Macquarie Dictionary Online (2012) defines 'air' as "a mixture of oxygen, nitrogen and other gases, which surrounds the earth and forms its atmosphere". The primary medium of operation for the Air Combat system is the air. In particular, the Air Combat system must be capable of functioning within the air environment for extensive periods of time prior to being grounded.

Ground:

'Ground' is defined as "the solid surface of the earth" (Macquarie Dictionary Online, 2012). This definition is essential to the current analysis as it distinguishes ground from air, the two environments within which the Air Combat system is designed to operate. As such, air combat piloting encapsulates the ability of the Air Combat system to move as required when on the ground.

Preferred route:

The Collins Dictionary Online (2012) describes the term 'preferred' as "to like better or value more highly", with route defined as "a way or course taken in getting from a starting point to a destination" (Oxford Dictionary Online, 2012). The Air Combat system must be capable of moving, where possible, along a preferred course to achieve the purpose-related function of piloting. Importantly, however, a preferred route does not denote a prescribed route, as the Air Combat system must be capable of deviating from its planned flight path if unanticipated events (e.g., airborne enemy engagement) were to arise.

Rationale and supporting documentation:

- ❖ To satisfy the functional purpose of air combat, the Air Combat system must have the ability to move as required. This function allows air combat power to be generated and applied across air and surface domains, subsequently extending the protective reach of the Air Combat system:
 - "Air power is the ability to create or enable the creation of effects by or from platforms using the atmosphere for manoeuvre" (Royal Australian Air Force, 2008a, p. 3).

³⁷ Global Positioning System.

³⁸ Inertial Navigation System.

- “‘Manoeuvre warfare’ is the key strategic and operational concept influencing the way the Australian Defence Force conducts operations. This involves the movement and placement of forces in a favourable position relative to the enemy and the application of firepower such that the physical and psychological effect is sufficient to break an enemy’s will to continue fighting or otherwise conclude hostilities on Australia’s terms” (Australian Defence Force, 2005, Chapter 6, p. 2).
- “Air power’s range underpins the Air Force’s ability to manoeuvre and operate where and when needed, either alone in the strategic attack role or as part of a joint operation” (Royal Australian Air Force, 2008a, p. 82).
- ❖ To better understand the specific contribution of piloting to the Air Combat system, the fundamental concepts relating to this purpose-related function were explored through raw data analysis. Based on information extracted from Air Force and Defence publications, piloting, as a function, captures those capabilities which concern the directed movement of an aircraft. Though a relatively simple concept to understand, various mechanisms are involved to facilitate this end. Specifically, the air combat aircraft must be physically capable of moving (e.g., aerodynamic lift, thrust) and be mechanically capable of manipulating its movements (e.g., flight control, ground control) when directed:
 - “The role of the ADF Pilot is to operate an aircraft (fixed or rotary wing) to achieve mission objectives through use of appropriate tactics, operational procedures and effective employment of aircraft controls, systems and resources” (Capability Development Group, 2010, p. 1).

As the above statement suggests, the Air Combat system must be capable of regulating its movements during all portions of flight. This includes, but is not limited to, takeoff, climb, cruise, descent, and landing (US Navy, 2006).

- ❖ An additional aspect of air combat piloting concerns calculated movement. Specifically, the Air Combat system must be capable of directing itself, along a preferred route, to its destination as supported by navigational aids (e.g., GPS, INS):
 - “...air navigation is the process of determining the geographical position, and maintaining the desired direction, of an aircraft relative to the surface of the earth. Navigation information, which is the work product of positions in this occupation, is expressed in terms of position, direction, distance, and time. These are the four basic reference points used by navigators to direct the movement of the aircraft over long distances or to position it at a particular location and time to perform a specific assignment” (US Office of Personnel Management, 1988, p. 3).

These statements demonstrate that the Air Combat system must take into account a number of navigational parameters, such as altitude, longitude, latitude, and bearing, to reach its desired destination (i.e., combat target, Air Force base).

- ❖ Interconnected within air combat piloting are measures concerning precision/accuracy, timeliness, cost effectiveness (e.g., fuel resources), and safety. In particular, the Air Combat system must be capable of moving, primarily within the air environment, in a precise/accurate, timely, fuel efficient, and safe manner:
 - “Navigation is no longer a matter of merely getting from A to B safely, it is about doing this in a fuel-efficient manner, keeping to tight airline schedules, and avoiding other air traffic - commercial, general aviation, leisure and military” (Moir & Seabridge, 2006, p. 281).
- ❖ Air combat piloting is further enhanced by the capacity for range and endurance (see glossary for definitions) once airborne. Specifically, the Air Combat system must be capable of flying long distances from various bases, at home and abroad, either with, or without, air-to-air refuelling support. To achieve this end, the Air Combat system must monitor fuel usage and reserves for effective range and endurance:

- “Air Force’s range and speed enhances Australia’s capability to rapidly deploy military power across the nation and further afield as required by the Government” (Royal Australian Air Force, 2008a, p. 82).
- ❖ Other functions specific to the Air Combat system are reliant on air combat piloting to achieve their full operational potential. For example, to inflict lethal outcomes on a specified target (i.e., destruction purpose-related function), the Air Combat system must be capable of guiding itself to the required destination. Additionally, to protect itself from damage and/or destruction (i.e., self protection purpose-related function), the Air Combat system must be capable of guiding itself around potential or actual threats.

Glossary:

- ❖ *Aeronautical chart*: A specialised representation of mapped features of the Earth, or some part of it, produced to show selected terrain, cultural and hydrographic features, and supplemental information required for air navigation, pilotage, or for planning air operations (Department of Defence, 2012).
- ❖ *Airspace*: The zone next to the earth consisting of atmosphere capable of sustaining flight (Department of Defence, 2012).
- ❖ *Air-to-air refuelling*: The process of transferring fuel from one aircraft (the tanker) to another (the receiver) during flight (“Aerial refueling,” 2012).
- ❖ *Armament stores*: Generic term used to cover explosive ordnance, ordnance and small arms, non-explosive dangerous goods, and associated items (Department of Defence, 2012).
- ❖ *Aerodynamics*: The study of air in motion and of the forces acting on solids in motion relative to the air through which they move (Macquarie Dictionary Online, 2012).
- ❖ *Airborne*: Borne up, carried, or transported by air (Macquarie Dictionary Online, 2012).
- ❖ *Bearing*: The horizontal angle measured clockwise from a reference direction to a specified direction (Department of Defence, 2012).
- ❖ *Course*: The intended direction of movement in the horizontal plane (Department of Defence, 2012).
- ❖ *Direction*: The act of directing, pointing, aiming, etc. (Macquarie Dictionary Online, 2012).
- ❖ *Endurance*: The time an aircraft can continue flying, or a ground vehicle or ship can continue operating, under specified conditions e.g. without refuelling (Department of Defence, 2012).
- ❖ *Flight*: The action or process of flying through the air (Oxford Dictionary Online, 2012).
- ❖ *Flight path*:
 1. The actual or intended line of flight of an aircraft (Macquarie Dictionary Online, 2012).
 2. The line connecting the successive positions occupied, or to be occupied, by an aircraft, missile, or space vehicle as it moves through air or space (Department of Defence, 2012).
- ❖ *Flying*: Extending through the air (Macquarie Dictionary Online, 2012).
- ❖ *Latitude*: The angular distance of a place north or south of the earth’s equator, or of the equator of a celestial object, usually expressed in degrees and minutes (Oxford Dictionary Online, 2012).
- ❖ *Location*: A particular place or position (Oxford Dictionary Online, 2012).
- ❖ *Manoeuvre*:
 1. A movement or series of moves requiring skill and care (Oxford Dictionary Online, 2012).
 2. A large-scale military exercise of troops, warships, and other forces (Oxford Dictionary Online, 2012).

- ❖ *Payload*: In a missile or rocket, the warhead, its container and activating devices (Department of Defence, 2012).
- ❖ *Pitch*: The movement of an aircraft or ship about its transverse axis (Department of Defence, 2012).
- ❖ *Position*: The place, situation, or location of a person or thing (Collins Dictionary Online, 2012).
- ❖ *Propulsion*: The act of propelling or driving forward or onward (Macquarie Dictionary Online, 2012).
- ❖ *Operate/operating*: To work or use a machine, apparatus, or the like (Macquarie Dictionary Online, 2012).
- ❖ *Range*: The distance between any given point and an object or target (Department of Defence, 2012).
- ❖ *Roll*: The rotation of an aircraft or ship about its longitudinal axis (Department of Defence, 2012).
- ❖ *Routing*: A way or road taken or planned for passage or travel (Macquarie Dictionary Online, 2012).
- ❖ *Speed*: Rapidity in moving, going, travelling, or any proceeding or performance (Macquarie Dictionary Online, 2012).
- ❖ *Time*: A system or method of measuring or reckoning the passage of time (Macquarie Dictionary Online, 2012).
- ❖ *Yaw*: The rotation of an aircraft, ship or missile about its vertical axis so as to cause the longitudinal axis of the aircraft, ship or missile to deviate from the flight line or heading in its horizontal plane (Department of Defence, 2012).

SURVIVAL ASSISTANCE

Definition of Survival Assistance:

The function of 'survival assistance' is defined as the ability of the Air Combat system to [sustain](#) the [life](#) of its [aircrew](#) in [adverse situations](#) (as informed by the Macquarie Dictionary Online, 2012 definition for 'survive'). Specifically, in order to prevent fatalities, the Air Combat system must be capable of providing its crew members with mechanisms for survival when and where required.

[Sustain:](#)

The Oxford Dictionary Online (2012) defines 'sustain' as "strengthen or support physically or mentally". To attain air combat survival assistance, the Air Combat system must have the capacity to provide both physical and mental life saving measures for aircrew to use in the event of an emergency or unforeseen event. As such, life sustaining tools or supplies that are designed to aid survival, such as ejection systems, medical supplies, emergency signalling, shelter, and water/food, must be available within the Air Combat system.

[Life:](#)

The term 'life' is defined in a variety of ways. The Oxford Dictionary Online (2012) specifies 'life' as "the condition that distinguishes animals [used in the broadest sense of the term] and plants from inorganic matter, including the capacity for growth, reproduction, functional activity, and continual change preceding death", whereas the Macquarie Dictionary Online (2012) defines 'life' to be "a state or condition of existence as a human being". For the current analysis, aspects of both definitions will be utilised to represent life within air combat survival assistance. Specifically, life is an attribute of entities, in particular human beings, which have the capacity for growth, activity, and which are exclusively situated within the Air Combat aerial system. Therefore, air combat survival assistance principally functions to ensure and sustain the life of the aircrew.

[Aircrew:](#)

The term 'aircrew' is defined by the Macquarie Dictionary Online (2012) as "persons operating an aircraft in flight". For the Air Combat system, aircrew encompasses the air combat pilots and air combat officers (e.g., navigators).

[Adverse situations:](#)

The Oxford Dictionary Online (2012) defines 'adverse' as "preventing success or development; harmful; unfavourable", with 'situations' described as "a set of circumstances in which one finds oneself; a state of affairs" (Oxford Dictionary Online, 2012). As specific to air combat survival assistance, adverse situations refer to those circumstances which pose harm to the Air Combat system's aircrew. This may include, for example, being shot down by enemy air defence fighters or aircraft malfunction.

Rationale and supporting documentation:

- ❖ To achieve the air combat functional purpose, the Air Combat system must be capable of sustaining the life of its aircrew. This is of paramount importance to the RAAF as it currently operates with a limited personnel size³⁹, and allocates considerable resources towards training its air combat aircrew⁴⁰. To this end, maintaining aircrew life remains a key factor in ensuring airborne combat power into the future:

³⁹ The RAAF is a relatively small air force given its population and economic constraints (Royal Australian Air Force, 2008a, p. 112; Royal Australian Air Force, 2008b, p. 1). These constraints can have implications for recruitment, thus limiting the number of the personnel that can be readily employed. Consequently, those Air Force personnel that are currently serving are considered to be a valuable resource for the RAAF.

⁴⁰ To maintain a competent air combat force, the RAAF requires its aircrew to be highly trained, which can be considerably costly in both time and money. Therefore, sustaining the life of its air combat personnel is particularly important to the RAAF from a cost-benefit perspective.

- “My goal is to actively seek to eliminate injury, illness and occurrences in the workplace that degrade ACG’s preparedness and capability. To achieve this, we will strive for zero lost time, zero accidents and zero injury attributable to work processes, work environments, training and supervision” (Hupfeld, 2010).
- ❖ To better understand the Air Combat system’s requirement for survival assistance, the fundamental concepts relating to this purpose-related function were explored through raw data analysis. First, it was determined that the RAAF, ADF, and the Commonwealth are legally and morally required to provide a duty of care to their serving members/staff. Duty of care is defined as “the legal obligation to avoid causing harm to another person, especially through negligence” (Department of Defence, 2011). Specifically, organisations must ensure the health and safety of employees by adhering to a standard of reasonable care:
 - “People are my highest priority and are key to the delivery of Air Power; keeping our people safe and healthy is mandatory. We all have the responsibility for using training, resources and equipment to work safely. Further, maintaining a safe environment for all personnel working with Air Force is both a legal and moral responsibility” (Brown, 2011).
 - “...protecting and nurturing the whole team [as inclusive of the entire Defence community] will remain central to my focus as Air Force continues on its successful path. To this end, I emphasise my commitment to Air Force safety, because we have a duty of care to all of our members” (Brown, 2011).

As the above statements demonstrate, the RAAF, ADF, and Commonwealth have a collective duty of care to their employees. For air combat, this duty of care extends to the aircrew of the Air Combat system. Therefore, the aircrew are legally and morally owed the safest environment practically possible despite operating in extremely threatening, life endangering situations.

- ❖ The Air Combat system is engineered to operate in inherently dangerous environments. This danger can emerge from a myriad sources, be it hostile/enemy interaction/s, extreme temperatures, or the geography/terrain (e.g., mountainous). To mitigate against these potential dangers, the air combat aircraft must be capable of providing life support to its aircrew when required:
 - “From an organisational perspective, to do dangerous things safely we must apply a disciplined, systematic approach to safety” (Brown, 2011).
 - “Military flying operations have always carried an inherent risk. Whilst most aircrew won’t spend too much time dwelling on the possibility of being stranded on the ground, it is a distinct possibility” (Combat Survival Training School, 2011).
 - “The military operates in a high-risk environment” (Australian Defence Force, 2009, p. 43).
 - “...there are inherent lethal risks involved to aircrew in the pursuit of the physical destruction of an adversary” (Butler, 2008, p. 23-24).

These statements indicate that the RAAF and ADF understand the safety implications for military aircraft operating in distinctly unsafe environments. The Air Combat system, like all other airborne platforms within the RAAF, must have the capacity to employ appropriate survival capabilities in the event that an emergency situation arises.

- ❖ To meet the requirements of the function of survival assistance, the Air Combat system must be capable of supporting its aircrew in all adverse situations. For example, if the Air Combat system loses flight capacity as a result of enemy action (air or ground based), internal malfunction, or aircrew (pilot/air combat officer) error, it must have the capability to sustain the life of its aircrew where practically possible:

- "Involvement in armed conflict dramatically increases the chances of being in a survival situation. Armed conflict adds the extra element of enemy pursuit, making survival even more difficult" (Combat Survival Training School, 2004c, p. 1).
 - "Aircrew flying in a hostile environment can be forced down at any time for a number of reasons" (Combat Survival Training School, 2004c, p. 5).
 - "The probability of casualties resulting from an incident leading to a survival situation is quite high e.g. as a result of aircraft crash, shipwreck, vehicle accident, etc." (Combat Survival Training School, 2004a, p. 1).
- ❖ The Air Combat system must be capable of contingency planning for effective survival assistance. Air combat crew members are trained in survival methods and techniques in the event of an emergency. Correct use of life support components, like ejection systems and individual survival stores (inclusive of first aid, food/water, etc.), increase the likelihood of aircrew survival:
- "Safe airborne operations are enabled by high levels of collective training and a range of technical equipment and certification processes which ensure a high degree of safety and confidence" (Australian Defence Force, 2011, Chapter 2, p. 3).
 - "With a high risk of combat damage, it is essential that military aircrew have the ability to abandon the aircraft" (Australian Defence Force, 2004, Chapter 9, p. 1).
- ❖ In supporting the Air Combat system in survival situations, other Air Force platforms (e.g., C-130 Hercules) and crew personnel (e.g., Search and Rescue, Aeromedical Evacuation teams) are often required to provide additional survival assistance to sustain and maintain aircrew life:
- "Aircrew and passengers in aircraft flying over the sea could be forced to 'ditch' their aircraft into the open ocean following an emergency where it is either not possible, or practical, to continue flying for a land based recovery" (Combat Survival Training School, 2004b, p. 1).

Glossary:

- ❖ *Basic survival*: The application of elementary techniques, skills and methods that aid existence when removed from the normal lines of communication and supply (Department of Defence, 2012).
- ❖ *Combat survival*: Those measures to be taken by service personnel when involuntarily separated from friendly forces in combat, including procedures relating to individual survival, evasion, escape, and conduct after capture (Department of Defence, 2012).
- ❖ *Duty of care*: Duty of care is the legal obligation to avoid causing harm to another person, especially through negligence. The Occupational Health and Safety (Commonwealth Employment) Act 1991 (the OHS Act) places a duty of care on the Defence Organisation to take all reasonably practicable steps to ensure the health and safety of employees at work (Department of Defence, 2012).
- ❖ *Emergency*: An unforeseen occurrence; a sudden and urgent occasion for action (Macquarie Dictionary Online, 2012).
- ❖ *Existence*: The continuance or maintenance of life; living, especially in adverse circumstances (Collins Dictionary Online, 2012).
- ❖ *Fatal*: Causing death; causing destruction or ruin (Macquarie Dictionary Online, 2012).
- ❖ *Non-fatal*: Bodily harm resulting from severe exposure to an external force or substance (mechanical, thermal, electrical, chemical, or radiant) or submersion. This bodily harm can be unintentional or violence-related (US Department of Health and Human Sciences, Centers for Disease Control and Prevention, 2007).

- ❖ *Recovery operations*: Operations conducted to search for, locate, identify, recover, and return isolated personnel, human remains, sensitive equipment, or items critical to national security (Department of Defence, 2012).
- ❖ *Rescue*: To free or deliver from confinement, violence, danger, or evil (Macquarie Dictionary Online, 2012).
- ❖ *Staff*: In a military organisation, a group of military and civilian personnel assisting a commander in all his/her functions (Department of Defence, 2012).
- ❖ *Survival*: The act of continuing to live or exist (Department of Defence, 2012).

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58. Williams, K. S. (2007). *Expanding emerging Non-Traditional ISR (NTISR) collection and network-centric warfare (NCW) capabilities: A doctrinal shift?* (Unpublished research report). Maxwell Air Force Base, AL: Air Command and Staff College, Air University.

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Appendix E: Air Combat Capability Object-related Processes and Physical Objects Glossary

This appendix presents an unclassified glossary developed for the Air Combat Capability object-related processes and physical objects. Each object-related process and physical object is defined at the subsystem and component level of decomposition. The physical objects represented within this glossary each have an accompanying image which provides a generic representation of that object.

AERIAL SYSTEM***Definition:***

- The aerial system will be classified as any airborne structure that is part of the Air Combat Capability.
- Reference to any structural part of the Air Combat Capability aerial system (subsystems, components) will be in its most generic form in the first iteration of the analysis.

AIR VEHICLE SUBSYSTEM

Physical Object	Object-related Process
Air vehicle	Flight




Definition of Air vehicle:

- Any structure, machine, or contrivance, especially a vehicle, designed to be supported by the air, being borne up either by the dynamic action of the air upon the surfaces of the structure or object, or by its own buoyancy; such structures, machines, or vehicles collectively (National Aeronautics and Space Administration [NASA], 2001).

Definition of Flight:

- The National Aeronautics and Space Administration (NASA) describes the concept of 'flight' as "the movement of an object through the atmosphere or through space, sustained by aerodynamic, aerostatic, or reaction forces, or by orbital speed; especially, the movement of a man-operated or man-controlled device, such as a rocket, a space probe, a space vehicle, or aircraft" (2001). As specific to the Air Combat system, the object-related process for the air vehicle subsystem is that of flight. Specifically, each air vehicle component facilitates the Air Combat system in attaining and maintaining airborne movement.




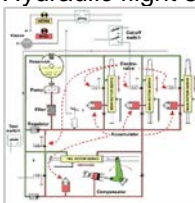
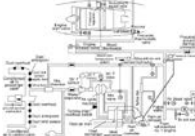
AIR VEHICLE COMPONENTS

Physical Object	Object-related Process
Airframe 	Aerodynamic lift
	Directional stability and control
Propulsion system 	Thrust
Dispenser system 	Weapons, chaff, and flare release

⁴¹ Image source: Boeing F/A-18E/F Super Hornet. (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/Boeing_F/A-18E/F_Super_Hornet.

⁴² Image of a Model F414. Image source: GE Aviation. (2012). Retrieved from <http://www.geaviation.com/engines/military/f414/>.

⁴³ Image of an AN/ALE-47(V) Threat-Adaptive Countermeasures Dispensing System (CMDS). Image source: Spar Aerospace Limited. (n.d.). Retrieved from <http://www.dougalco.com/spar/apmil04.htm>.

Power supply system  44	Electrical power supply
Fuel supply system  45	Fuel storage and supply
Landing gear  46	Ground supply and movement
Hydraulic flight system  47	Hydraulic power supply
Environmental control system (ECS)  48	Environmental control

Airframe:

The 'airframe' of an aircraft is defined as the "whole body of an aeroplane without its engines" (Macquarie Dictionary Online, 2012) and as "the structure of an aircraft without the power plant" (Merriam-Webster Dictionary Online, 2012). This includes, but is not necessarily limited to, the wings, vertical and horizontal tail, and fuselage. Specifically, an airframe supports the aircraft in generating lift, directional stability and control, and affords volume ("Airframe," 2012), ultimately enabling the separate processes of aerodynamic lift and directional stability and control.

▪ Aerodynamic lift:

[Aerodynamic]: Able to travel through the air; designed for air travel (Macquarie Dictionary Online, 2012).

[Lift]: To move or bring (something) upwards from the ground or other support to some higher position (Macquarie Dictionary Online, 2012).

⁴⁴ Image of a DC power supply system. Image source: Recycled Goods. (n.d.). Retrieved from <http://www.recycledgoods.com/zoom.aspx?productID=21211>.

⁴⁵ Image of an aviation fuel transfer pump. Image source: Aviation Fuel Transfer Pump. (n.d.). Retrieved from <http://gpimalaysia.tripod.com/aviation-pump-system.html>.

⁴⁶ Image of a Super Hornet (F/A-18F) landing gear assembly. Image source: Aircraft Reference Articles: F/A-18F Super Hornet Part 1. (n.d.). Retrieved from <http://www.ipmslondon.ca/old%20site/ipmslondon.tripod.com/referencearticles/id16.html>.

⁴⁷ Diagram of a hydraulic flight system. Image source: Aviation Reports. (2005). Retrieved from http://www.tsb.gc.ca/eng/rapports-reports/aviation/2005/a05f0025/a05f0025_sec1.asp.

⁴⁸ Diagram of an aviation ECS. Image source: Environmental control system. (2012). In *Answers.com*. Retrieved from <http://www.answers.com/topic/environmental-control-system>.

- Directional stability and control:

[Directional]: Having a particular direction of motion, progression, or orientation (Oxford Dictionary Online, 2012).

[Stability]: Firmness in position (Macquarie Dictionary Online, 2012), with stable described as, relating to an object or structure, not likely to give way or overturn (Oxford Dictionary Online, 2012).

[Control]: To exercise restraint over or direction over; dominate; command (Macquarie Dictionary Online, 2012).

Propulsion system:

A machine that produces thrust to push an object forward (National Aeronautics Space Administration [NASA], 2010). The propulsion system contains engines which support the aircraft in achieving airborne thrust. Importantly, for aircraft cruising, the thrust from the propulsion system must be equivalent to the drag of the aircraft, and for aircraft acceleration, the thrust from the propulsion system must exceed the drag of the aircraft.

- Thrust:

[Thrust]: A pushing force or pressure exerted by a thing or a part against a contiguous one (Macquarie Dictionary Online, 2012).

Dispenser system:

The dispenser system works to dispense weapons, chaff, and flares as required (Merriam-Webster Online Dictionary, 2012), allowing these individual physical objects to meet their object-related processes.

- Weapons, chaff, and flare release:

[Weapon]: An offensive or defensive instrument of combat used to destroy, injure, defeat, or threaten an enemy (Department of Defence, 2012).

[Chaff]: Strips of frequency-cut metal foil, wire, or metallised glass fibre used to reflect electromagnetic energy, usually dropped from aircraft or expelled from shells or rockets as a radar countermeasure (Department of Defence, 2012).

[Flare]: A pyrotechnic designed to produce a source of light (Department of Defence, 2012).

[Release]: To free from anything that restrains (Macquarie Dictionary Online, 2012).

Power supply system:

A power supply system is the source of electrical power for a device, circuit, subsystem or system (Test Equipment Depot, 2011). It generates, regulates, and distributes internal electrical power throughout the aircraft. It can contain an AC (Alternating Current) system, a DC (Direct Current) system, and back up generators (Stout, n.d.; Wadia & GE Aircraft Engines, 2004).

- Electrical power supply:

[Electrical]: Concerned with, operating by, or producing electricity (Oxford Dictionary Online, 2012).

[Power]: Energy that is produced by mechanical, electrical, or other means and used to operate a device (Oxford Dictionary Online, 2012).

[Supply]: Make (something needed or wanted) available to someone; provide (Oxford Dictionary Online, 2012).

Fuel supply system:

The 'fuel supply system' is defined as those subcomponents which store and deliver fuel to the engine (S-Tech Enterprises, 2005). It is responsible for providing a reliable supply of fuel to the

propulsion system, and has the capacity to store fuel in the aircraft's wing tanks and external and structural tanks (Moir & Seabridge, 2008).

- Fuel storage and supply:

[Fuel]: Material used to feed an engine, as petrol, diesel, etc. (Macquarie Dictionary Online, 2012).

[Storage]: The action or method of storing something for future use (Oxford Dictionary Online, 2012), whereby storing is defined as to keep, set aside, or accumulate for future use (Collins Dictionary Online, 2012).

[Supply]: Make (something needed or wanted) available to someone; provide (Oxford Dictionary Online, 2012).

Landing gear:

The 'landing gear' is the structure that supports an aircraft on the ground and allows it to taxi, takeoff, and land ("Landing gear," 2012). It consists of the undercarriage legs and doors, steering and wheels, and brakes and anti-skid system (Moir & Seabridge, 2008). The landing gear system affords ground supply and movement as it provides the aircraft with the means to support and steer the aircraft on the ground and when in flight ("Undercarriage," 2012).

- Ground supply and movement:

[Ground]: The solid surface of the earth (Macquarie Dictionary Online, 2012).

[Supply]: Make (something needed or wanted) available to someone; provide (Oxford Dictionary Online, 2012).

[Movement]: To go or take from one place to another, change in location or position (Collins Dictionary Online, 2012).

Hydraulic flight system:

The hydraulic flight system is defined as a component which furnishes hydraulic fluid under pressure (includes pumps, regulators, lines, valves, etc.) to a common point (manifold) for redistribution to other defined systems (S-Tech Enterprises, 2005). It is primarily responsible for supplying power to operate several aircraft components such as landing gear, wing flaps, speed and wheel brakes, and flight controls (Brian, n.d.; Integrated publishing, n.d.).

- Hydraulic power supply:

[Hydraulic]: Denoting or relating to a liquid moving in a confined space under pressure (Oxford Dictionary Online, 2012).

[Power]: Energy that is produced by mechanical, electrical, or other means and used to operate a device (Oxford Dictionary Online, 2012).

[Supply]: Make (something needed or wanted) available to someone; provide (Oxford Dictionary Online, 2012).

Environmental control system (ECS):

An environmental control system (ECS) is a system that controls the environment in which the occupants of the aircraft function. It includes the supplemental oxygen, air-conditioning, heaters, and pressurisation systems, and any other feature that makes it comfortable for aircrew at all altitudes (McGraw-Hill Dictionary of Aviation, 2013).

- Environmental control:

[Environmental]: Of or relating to an environment or environments (Macquarie Dictionary Online, 2012).

[Control]: To exercise restraint over or direction over; dominate; command (Macquarie Dictionary Online, 2012).

MISSION CONTROL SUBSYSTEM

Physical Object	Object-related Process
Mission control	System management

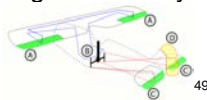



Definition of Mission control:

- The Macquarie Dictionary Online (2012) defines 'mission' as "an operation on land, sea, or in the air, carried out by an armed force against an enemy", with 'control' described as "to exercise restraint over or direction over; dominate; command". As specific to the Air Combat system, the mission control subsystem refers to those physical objects that are purposively designed to manage air combat missions, from lift-off until landing or the end of the mission.

Definition of System management:

- The Department of Defence (2012) describes a 'system' as "a combination or assembly of hardware, software, principles, doctrines, methods, ideas, procedures and personnel, or any combination of these, arranged or ordered towards a common objective", with 'management' defined as "having executive control or authority" (Oxford Dictionary Online, 2012). As the mission control subsystem integrates and coordinates with the other subsystems of the aerial system (e.g., navigation subsystem, communication subsystem), its primary capability is to afford executive control of all the Air Combat system's avionic subsystems. For the purposes of the current analysis, this will be labelled 'system management'.

MISSION CONTROL COMPONENTS

Physical Object	Object-related Process
Flight control system 	Flight control
Mission computer 	Mission computing
Workstations 	Information display
Flight management system (FMS) 	Flight management

⁴⁹ Image of a typical aircraft's primary flight controls. Image source: Aircraft flight control system. (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/Aircraft_flight_control_system.

⁵⁰ Image of a General Dynamic Advanced Mission Computer (AMC). Image source: Military and Aerospace Electronics. (2013). *General Dynamics gets urgent maintenance order for mission-critical Navy combat jet computers*. Retrieved from <http://www.militaryaerospace.com/articles/2013/05/GD-flight-computers.html>.

⁵¹ Image of a typical workstation for an air combat aircraft. Image source: Hoff, M. (2012). *Boeing builds Super Hornet digital displays for possible 2015 upgrade*. In *DefenseTech.org*. Retrieved from <http://defensetech.org/2012/09/17/boeing-builds-super-hornet-digital-displays-for-possible-2015-upgrade/>.

⁵² An example of a FMS computer. Image source: Flight management system. (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/Flight_management_system.

Flight control system:

The flight control system is described as equipment which seeks to automatically control the flight of an aircraft to a path or altitude described (Department of Defence, 2012). It enables the pilot to exercise control over the aircraft when in flight. It consists of flight control surfaces, cockpit controls (primary: joystick, rudder pedals, throttle controls; secondary: wings flaps, air brakes, spoilers), connecting linkages, and the necessary operating mechanisms to control an aircraft's direction of flight ("Aircraft flight control system," 2012; Moir & Seabridge, 2006).

- Flight control:

[Flight]: The movement of an object through the atmosphere or through space, sustained by aerodynamic, aerostatic, or reaction forces, or by orbital speed; especially, the movement of a man-operated or man-controlled device, such as a rocket, a space probe, a space vehicle, or aircraft (National Aeronautics Space Administration [NASA], 2001).

[Control]: To exercise restraint over or direction over; dominate; command (Macquarie Dictionary Online, 2012).

Mission computer:

The mission computer is an integrated information processing system which seeks to manage and fuse the aircraft's avionics (e.g., sensors) and weapons subsystem. Additional information will be collated once known.

- Mission computing:

[Mission]: An operation on land, sea, or in the air, carried out by an armed force against an enemy (Macquarie Dictionary Online, 2012).

[Computing]: The use or operation of computers (Oxford Dictionary Online, 2012), whereby a computer is an electronic device which is capable of receiving information (data) in a particular form and of performing a sequence of operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals (Oxford Dictionary Online, 2012).

Workstations:

A workstation is described as the place which the aircrew works including the equipment, furniture and fittings (Department of Defence, 2012). Workstation equipment encompasses displays (e.g., Cathode Ray Tube [CRT] and Liquid Crystal Display [LCD]) and digital map sets. These displays enable certain types of information (e.g., engine fuel, location) to be shown to the aircrew.

- Information display:

[Information]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

[Display]: An electronic device for the visual presentation of data or images (Oxford Dictionary Online, 2012).

Flight management system (FMS):

The flight management system (FMS) is defined as a specialised computer system that automates a wide variety of in-flight tasks ("Flight management system," 2012). The FMS provides the primary navigation, flight planning and optimised route determination and en route guidance for the aircraft (Walter, 2001).

- Flight management:

[Flight]: The movement of an object through the atmosphere or through space, sustained by aerodynamic, aerostatic, or reaction forces, or by orbital speed; especially, the movement of a man-operated or man-controlled device, such as an aircraft or space vehicle (National Aeronautics Space Administration [NASA], 2001).

[Management]: Having executive control or authority (Oxford Dictionary Online, 2012).

NAVIGATION SUBSYSTEM

Physical Object	Object-related Process
Navigation	Localisation






Definition of Navigation:

- The process or activity of accurately ascertaining one's position and planning and following a route (Oxford Dictionary Online, 2012).

Definition of Localisation:

- The Collins Dictionary Online (2012) describes the term 'localisation' as "to assign or ascribe to a particular region". The primary capability afforded by the navigation subsystem is the ability to localise the Air Combat system to a particular region, specifically referred to in the current analysis as 'localisation'.

NAVIGATION COMPONENTS

Physical Object	Object-related Process
Global positioning system (GPS)  53	Position, velocity, and time information
Inertial navigation system (INS)  54	Position, orientation, and velocity calculation
Radar altimeter  55	Altitude calculation
Tactical air navigation (TACAN)  56	Distance and bearing calculation
Precision landing guidance system (PLGS)  57	Precision approach

⁵³ Image source: Garmin. (2012). *What is a GPS?* Retrieved from <http://www8.garmin.com/aboutGPS/>.

⁵⁴ Image source: Northrop Grumman. (2012). *LN-94 Inertial Navigation System*. Retrieved from <http://www.es.northropgrumman.com/solutions/ln94/index.html>.

⁵⁵ Image source: US Navy (NAVAIR). (n.d.). *Target Systems: AN/APN-194 Radar altimeter*. Retrieved from http://www.navair.navy.mil/pma208/?fuseaction=controller.target_view&target_id=4&type=taas.

⁵⁶ Image source: NavCom Defense Electronics. (n.d.). *AN/URN-25 TACAN*. Retrieved from http://www.navcom.com/navigation_systems.htm.

Global positioning system (GPS):

A global positioning system (GPS) is a satellite based United States Department of Defense program that provides specially coded satellite signals that can enable a receiver to compute position, velocity and time (Department of Defence, 2012).

- Position, velocity, and time information:

[Position]: Condition with reference to place, location (Macquarie Dictionary Online, 2012).

[Velocity]: Rate of motion, especially when the direction of motion is also specified (Macquarie Dictionary Online, 2012).

[Time]: 1. A quantity measuring duration, usually with reference to a periodic process such as the rotation of the earth or the vibration of electromagnetic radiation emitted from certain atoms (Collins Dictionary Online, 2012). 2. A specific point on this continuum expressed in terms of hours and minutes (Collins Dictionary Online, 2012).

[Information]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

Inertial navigation system (INS):

An inertial navigation system (INS) is a self-contained navigation system using inertial detectors, which automatically provides vehicle position, heading and velocity (Department of Defence, 2012).

- Position, orientation, and velocity calculation:

[Position]: Condition with reference to place, location (Macquarie Dictionary Online, 2012).

[Orientation]: The adjustment or alignment of oneself to surroundings or circumstances (Collins Dictionary Online, 2012).

[Velocity]: Rate of motion, especially when the direction of motion is also specified (Macquarie Dictionary Online, 2012).

[Information]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

Radar altimeter:

A radar altimeter measures altitude above the terrain presently beneath an aircraft or spacecraft ("Radar altimeter," 2012).

- Altitude calculation:

[Altitude]: The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (Department of Defence, 2012).

[Calculation]: A mathematical determination of the amount or number of something (Oxford Dictionary Online, 2012).

Tactical air navigation (TACAN):

A tactical air navigation (TACAN) system is an ultra high frequency electronic instrument, able to provide continuous bearing and slant range to a selected station (Department of Defence, 2012).

- Distance and bearing calculation:

[Distance]: The space between known reference points or a ground observer and a target, measured in metres (artillery), in yards (naval gunfire), or in units specified by the observer (Department of Defence, 2012).

⁵⁷ Image source: Rockwell Collins. (2012). AN/ARN-147 (V) VOR/ILS/GS/MB Receiver. Retrieved from <http://rockwellcollins.com/sitecore/content/Data/Products/Navigation and Guidance/Radio Navigation and Landing/AN-ARN-147V VOR-ILS-GS-MB Receiver.aspx>.

[[Bearing](#)]: The horizontal angle measured clockwise from a reference direction to a specified direction (Department of Defence, 2012).

[[Calculation](#)]: A mathematical determination of the amount or number of something (Oxford Dictionary Online, 2012).

[Precision landing guidance system \(PLGS\)](#):

A precision landing guidance system (PLGS) describes a family of systems that provide precision approach and landing capability (Global Defence, 2011). It is a generic label for a group of landing guidance systems.

- [Precision approach](#):

[[Precision](#)]: The quality, condition, or fact of being exact and accurate (Oxford Dictionary Online, 2012).

[[Approach](#)]: To come nearer or near to (Macquarie Dictionary Online, 2012).

COMMUNICATION SUBSYSTEM

Physical Object	Object-related Process
Communication	Information transmission




Definition of Communication:

- An assembly of equipment, methods and procedures and, if necessary, personnel, organised to accomplish information transfer functions (Department of Defence, 2012).
- The act or fact of communicating; transmission (Macquarie Dictionary Online, 2012).

Definition of Information transmission:

- The concept of 'information' has been defined in a variety of ways. The Royal Australian Air Force and North Atlantic Treaty Organisation (Department of Defence, 2012) describe 'information' as "unprocessed data of every description which may be used in the production of intelligence", with the US Joint military (Department of Defence, 2012) constructing it as "facts, data, or instructions in any medium or form". Based on both these definitions, information, as specific to the communication subsystem, refers to data, facts, or instructions in any medium or form (e.g., voice data, digital data). Furthermore, 'transmission' is defined as "the act of transmitting" (Macquarie Dictionary Online, 2012), with 'transmitting' described as "to send over or along, as to a recipient or destination; forward, dispatch, or convey" (Macquarie Dictionary Online, 2012). As specific to the Air Combat system, the process that is afforded by the communication subsystem is that of information transmission, specifically to convey data/facts/instruction to those entities that require it.

COMMUNICATION COMPONENTS

Physical Object	Object-related Process
High Frequency (HF) radio  58	Long distance, voice transmission
Very High Frequency (VHF) radio  59	Medium distance, voice transmission
Ultra High Frequency (UHF) radio  60	Short distance, voice transmission

⁵⁸ Image source: DPD Productions. (n.d.). *Military Radios: AN/ARC-220*. Retrieved from http://www.dpdproductions.com/page_milradios.html.

⁵⁹ Image source: Global Security. (2012). *AN/ARC-186 Airborne VHF AM/FM Transceiver*. Retrieved from http://www.globalsecurity.org/military/systems/ground/an_arc186.htm.

⁶⁰ Image source: DPD Productions. (n.d.). *Military Radios: AN/ARC-164*. Retrieved from http://www.dpdproductions.com/page_milradios.html.

Link 11  61	Beyond Line-Of-Sight (BLOS) digital data transmission
Link 16  62	Line-Of-Sight (LOS) digital and imagery data, and voice transmission
Link 22  63	Enhanced Beyond Line-Of-Sight (BLOS) digital data transmission
Inter-communications system (ICS)  64	Internal voice data
Common data link  65	Imagery data
Radio beacon set  66	Emergency signalling data

High Frequency (HF) radio:

A High Frequency (HF) radio (as defined in additional detail below) is a radio system which operates between 3 and 30 MHz within the radiofrequency spectrum. It is capable of transmitting long distance communications (e.g., air-to-air and air-to-surface) in the form of voice data ("High frequency," 2012).

[HF]: The radiofrequency spectrum band or any frequency in the band between 3 and 30 MHz (Department of Defence, 2012).

[Radio]: The use of electromagnetic waves, lying in the radiofrequency range, for broadcasting, two-way communications (Collins Dictionary Online, 2012).

⁶¹ Image source: DRS Technologies. (2010). *Products and Services: Secure High-Speed Information Networking*. Retrieved from <http://www.drs.com/Products/Communication/Datalinks.aspx>.

⁶² Image source: BAE Systems. (n.d.). *Small Adaptable Form Factor (SAFF) Link 16*. Retrieved from http://www.baesystems.com/product/BAES_055454/small-adaptable-form-factor-saff-link-16?_afLoop=421385867794000&_afWindowMode=0&_afWindowId=null&baeSessionId=pY6jQGxJmsTWTNHQz2hDJvhbqv23sx8Tnz49xX9XSCDky5JcZbXBI-1946851151.

⁶³ Image source: Via Sat. (2012). *Link 22 Link Level COMSEC (LLC)*. Retrieved from <http://www.viasat.com/government-communications/information-assurance/link-22-link-level-comsec-llc>.

⁶⁴ Image source: Naval Technology.com. (2011). *Esterline Palomar Products – Secure Communications Management Systems, CCS-2100 intercommunications system*. Retrieved from <http://www.naval-technology.com/contractors/navigation/esterline/>.

⁶⁵ Image source: Industry Cortex. (n.d.). *Tactical Common Data Link – Airborne Terminal*. Retrieved from <http://www.industrycortex.com/products/profile/7585580/tactical-common-data-link-airborne-terminal>.

⁶⁶ Image source: Jerry Proc. (2012). *Orca Class PCT's*. Retrieved from <http://jproc.ca/rp/rp2/orca.html>.

- Long distance, voice transmission:

[Long distance]: Over 3,000 kilometres (Codan Radio, n.d.; definition is specific to this type of physical object).

[Voice]: The sound made by the vibration of the vocal cords, especially when modified by the tongue and mouth (Collins Dictionary Online, 2012).

[Transmission/transmitting]: To send over or along, as to a recipient or destination; forward, dispatch, or convey (Macquarie Dictionary Online, 2012).

Very High Frequency (VHF) radio:

A Very High Frequency (VHF) radio (as defined in additional detail below) is a radio system which operates between 30 to 300 MHz within the radiofrequency spectrum (Department of Defence, 2012). It is capable of transmitting signals within line-of-sight (direct), and up to several tens of kilometres (Department of Defence, 2012; "Very high frequency," 2012). Given these capabilities, for the purposes of the current analysis the VHF radio will be considered capable of transmitting medium distance communications.

[VHF]: The radiofrequency spectrum band or any frequency in the band between 30 and 300 MHz, used for mobile radio telephone, television, broadcasting and line-of-sight communications (Department of Defence, 2012; "Very high frequency," 2012).

[Radio]: The use of electromagnetic waves, lying in the radiofrequency range, for broadcasting, two-way communications (Collins Dictionary Online, 2012).

- Medium distance, voice transmission:

[Medium distance]: Has the potential to travel extremely long distances (i.e., several tens of kilometres, beyond line-of-sight) into space when not obstructed (e.g., objects, mountains) ("Very high frequency," 2012; definition is specific to this type of physical object).

[Voice]: The sound made by the vibration of the vocal cords, especially when modified by the tongue and mouth (Collins Dictionary Online, 2012).

[Transmission/transmitting]: To send over or along, as to a recipient or destination; forward, dispatch, or convey (Macquarie Dictionary Online, 2012).

Ultra High Frequency (UHF) radio:

An Ultra High Frequency (UHF) radio (as defined in additional detail below) is a radio system which operates between 300 and 3000 MHz (0.3 to 3 GHz) within the radiofrequency spectrum (Department of Defence, 2012). It is primarily used for short distance communications or for high flying aircraft ("Ultra high frequency," 2012).

[UHF]: The radiofrequency spectrum band or any frequency in the band between 300 and 3000 MHz (or 0.3 and 3 GHz), used for radars and radio relay microwave communications (Department of Defence, 2012).

[Radio]: The use of electromagnetic waves, lying in the radiofrequency range, for broadcasting, two-way communications (Collins Dictionary Online, 2012).

- Short distance, voice transmission:

[Short distance]: Within a radius of 40-50 kilometres (Australian Customs Service, 2008; this definition is specific to this type of physical object).

[Voice]: The sound made by the vibration of the vocal cords, especially when modified by the tongue and mouth (Collins Dictionary Online, 2012).

[Transmission/transmitting]: To send over or along, as to a recipient or destination; forward, dispatch, or convey (Macquarie Dictionary Online, 2012).

Link 11:

Link 11 is described as a secure, half-duplex, networked digital data link using parallel transmission frame characteristics and standard message formats at either 1364 or 2250 bits per second (bps) (Department of Defence, 2012). It has a beyond line-of-sight capability, and can exchange data among airborne, land-based, and maritime data systems ("Link 11," 2012).

- BLOS digital data transmission:

[BLOS (Beyond Line-of-Sight)]: Not limited by direct line of sight between system and target. In communications, this means that the transmitter and receiver can form a link without a direct, clear path to each other (Knight & Luck, 2007).

[Digital]: Of, relating to, resembling, or possessing a digit or digits (Collins Dictionary Online, 2012).

[Data]: Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means (Department of Defence, 2012).

[Transmission/transmitting]: To send over or along, as to a recipient or destination; forward, dispatch, or convey (Macquarie Dictionary Online, 2012).

Link 16:

Link 16 is described as a secure, high capacity, jam-resistant, nodeless data link which offers a line-of-sight capability. It is proficient in transmitting high capacity voice and digital data (e.g., text messages, imagery) in real time (Department of Defence, 2012; "Link 16," 2012).

- LOS digital and imagery data, and voice transmission:

[LOS (Line-of-Sight)]: Requiring a relatively unobstructed path from transmitter to receiver or from sensor to target (Knight & Luck, 2007).

[Digital]: Of, relating to, resembling, or possessing a digit or digits (Collins Dictionary Online, 2012).

[Imagery]: Collectively, the representations of objects reproduced electronically or by optical means on film, electronic display devices, or other media (Department of Defence, 2012).

[Data]: Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means (Department of Defence, 2012).

[Voice]: The sound made by the vibration of the vocal cords, especially when modified by the tongue and mouth (Collins Dictionary Online, 2012).

[Transmission/transmitting]: To send over or along, as to a recipient or destination; forward, dispatch, or convey (Macquarie Dictionary Online, 2012).

Link 22:

Link 22 is described as a secure, electronic countermeasure resistant, flexible, medium speed tactical data link designed to replace Link 11 and supplement Link 16 (Department of Defence, 2012). It has a more secure and stronger encryption and coding link than Link 11, and provides a beyond line-of-sight communications feed not met by Link 16. It is capable of transmitting digital data across air, surface, subsurface, and ground-based tactical data systems ("Link 22," 2012).

- Enhanced BLOS digital data transmission:

[Enhance]: 'Enhanced' is defined as to "intensify, increase, or further improve the quality, value, or extent of" (Oxford Dictionary Online, 2012). When applied to the object-related process label for Link 22, the term 'enhanced' signifies the improved capacity for BLOS digital data transmission in comparison to that provided by Link 11.

[BLOS (Beyond Line-of-Sight)]: Not limited by direct line of sight between system and target. In communications, this means that the transmitter and receiver can form a link without a direct, clear path to each other (Knight & Luck, 2007).

[[Digital](#)]: Of, relating to, resembling, or possessing a digit or digits (Collins Dictionary Online, 2012).

[[Data](#)]: Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means (Department of Defence, 2012).

[[Transmission/transmitting](#)]: To send over or along, as to a recipient or destination; forward, dispatch, or convey (Macquarie Dictionary Online, 2012).

[Inter-Communications System \(ICS\):](#)

An inter-communication system (ICS) is described as an internal or closed audio system, as within an aircraft, ship, etc. (Macquarie Dictionary Online, 2012). It is capable of providing rapid and easy data transmittance between the crew members of an aircraft, ship, etc. ("Intercom," 2012).

- [Internal voice data:](#)

[[Internal](#)]: Situated or existing in the interior of something (Macquarie Dictionary Online, 2012).

[[Voice](#)]: The sound made by the vibration of the vocal cords, especially when modified by the tongue and mouth (Collins Dictionary Online, 2012).

[[Data](#)]: Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means (Department of Defence, 2012).

[Common data link:](#)

A common data link is a secure (jam resistant), full-duplex, point-to-point device used to exchange large amounts of images, videos and signals data ("Common data link," 2012; Department of Defence, 2012; "Microwave transmission," 2012).

- [Imagery data:](#)

[[Imagery](#)]: Collectively, the representations of objects reproduced electronically or by optical means on film, electronic display devices, or other media (Department of Defence, 2012).

[[Data](#)]: Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means (Department of Defence, 2012).

[Radio beacon set:](#)

A radio beacon set is a radio transmitter which emits a distinctive, or characteristic, signal used for the determination of bearings, courses, or locations (Department of Defence, 2012). In the event of an emergency (i.e., aircraft malfunction), the radio beacon transmits signals which can be detected by aircraft within a specific range, and by orbiting satellites ("Electric beacon," 2012).

- [Emergency signalling data:](#)

[[Emergency](#)]: A serious, unexpected, and often dangerous situation requiring immediate action (Oxford Dictionary Online, 2012).

[[Signalling](#)]: Convey information or instructions by means of a gesture, action, or sound (Oxford Dictionary Online, 2012).

[[Data](#)]: Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means (Department of Defence, 2012).

SENSOR SUBSYSTEM

Physical Object	Object-related Process
Sensor	Sensing


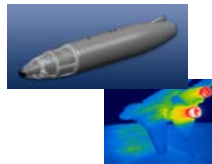

Definition of Sensor:

- A device which detects or measures a physical property (i.e., objects, activities) and records, indicates, or otherwise responds to it (adapted definition from Department of Defence, 2012; Oxford Dictionary Online, 2012).

Definition of Sensing:

- The Oxford Dictionary Online (2012) defines 'sensing' as to "perceive by a sense or senses", with 'perceive' described as to "gain knowledge of through one of the senses; discover by seeing, hearing, etc." (Macquarie Dictionary Online, 2012). As specific to the Air Combat system, the sensor subsystem affords the process of perceiving, specifically gaining information, which is collectively referred to in the current analysis as 'sensing'.



SENSOR COMPONENTS

Physical Object	Object-related Process
Radio detection and ranging (Radar)  67	Range, azimuth, and elevation information
Infra-red (IR)  68	Size and shape information
Identification friend or foe (IFF)  69	Identity information

⁶⁷ Image of a radio detection and ranging device (radar). Image source: Defense Industry Daily. (2012). *Raytheon's APG-79 AESA Radars*. Retrieved from <http://www.defenseindustrydaily.com/new-apg79-aesa-radars-for-super-hornets-0411/>. Resulting imagery produced by a radar. Image source: Warplanes Online Community. (2012). *F-15 intercepted in effect of TFR*. Retrieved from <http://community.warplanes.com/tag/f-15-fighters/>.

⁶⁸ Image of an IR sensor. Image source: Aviation News. (2012). *Lockheed Martin's SpectIR IRST System Demonstrates Capability During Air National Guard Live Fire Test*. Retrieved from <http://www.aviationnews.eu/2012/02/24/lockheed-martins-spectir-irst-system-demonstrates-capability-during-air-national-guard-live-fire-test/>. Resulting imagery produced by an infra-red sensor. Image source: Infrared Cameras. (2012). *Digital IR cameras applications in military*. Retrieved from <http://www.infraredcamerasinc.com/Thermography-Articles/Military-Security-Surveillance/Digital-IR-cameras-applications-in-military.html>.

⁶⁹ Image source: Chosun.com. (2008). *AN/APX-111 Combined Interrogator and Transponder*. Retrieved from http://bemil.chosun.com/nbrd/gallery/view.html?b_bbs_id=10044&num=56204.

Electronic support measures (ESM)  70	Presence and bearing information
Electro optical (EO)  71	Presence, size, shape, azimuth, and elevation information

Radio detection and ranging:

A radio detection and ranging device (radar) provides information on range, azimuth, and/or elevation of objects (Department of Defence, 2012). It is capable of locating and tracking entities in the air, ground or sea, and warning the aircrew of obstacles in or approaching their path ("Radar," 2012).

▪ Range, azimuth, and elevation information:

[Range]: The distance between two objects, usually an observation point and an object under observation (National Aeronautics and Space Administration [NASA], 2001).

[Azimuth]: The horizontal angle, measured clockwise by degrees or mils between a reference direction and the line to an observed or designated point (Department of Defence, 2012).

[Elevation]: The vertical distance of a point or level, on, or affixed to, the surface of the earth, measured from mean sea level (Department of Defence, 2012).

[Information]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

Infra-red (IR):

Infra-red (IR) is defined as "part of the electromagnetic spectrum with wavelengths approximately between about 20 microns and about 1 millimetre" (Macquarie Dictionary Online, 2012). IR sensors allow aircrews to get visuals on entities at night by using thermal imagery/heat seeking technology. They are primarily employed to provide size and shape information to the aircrew ("Infrared," 2012; "Thermal radiation," 2012).

▪ Size and shape information:

[Size]: The dimensions, proportions, or magnitude of anything (Macquarie Dictionary Online, 2012).

[Shape]: The external form, contours, or outline of someone or something (Oxford Dictionary Online, 2012).

⁷⁰ Image source: Selex Galileo. (2012). *Electronic Warfare*. Retrieved from http://www.selexgalileo.com/SelexGalileo/EN/Business/Products/Electronic_Warfare/index.sdo.

⁷¹ Image of an EO sensor found on the F-35 Lightning II. Image source: World Military Forum – Latest Military News. (2009). *Lockheed Martin Delivers First Production F-35 Lightning II Electro-Optical Targeting System (EOTS)*. Retrieved from <http://www.armybase.us/2009/11/lockheed-martin-delivers-first-production-f-35-lightning-ii-electro-optical-targeting-system-eots/>. Resulting imagery produced by an electro optical sensor. Image source: World Military Forum – Latest Military News. (2009). *Lockheed Martin Delivers First Production F-35 Lightning II Electro-Optical Targeting System (EOTS)*. Retrieved from <http://www.armybase.us/2009/11/lockheed-martin-delivers-first-production-f-35-lightning-ii-electro-optical-targeting-system-eots/>.

[**Information**]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

Identification friend or foe (IFF):

An identification friend or foe (IFF) is a system using electromagnetic transmissions to which equipment carried by friendly forces automatically responds, for example, by emitting pulses, thereby distinguishing themselves from enemy forces (Department of Defence, 2012). It is used for air traffic purposes and radar identification for intercept.

- Identity information:

[**Identity**]: Individual characteristics by which a person or thing is recognised (Collins Dictionary Online, 2012).

[**Information**]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

Electronic support measures (ESM):

An electronic support measures (ESM) sensor is a device which is capable of searching for, intercepting and identifying electromagnetic emissions, and in locating their sources for the purpose of immediate threat recognition (Department of Defence, 2012). It is capable of gathering intelligence by passively listening to electromagnetic radiations of military interest ("Electronic warfare support measures," 2012). This ultimately enables the aircraft to gain presence and bearing information relating to a specified entity.

- Presence and bearing information:

[**Presence**]: The general existence of a specified entity (see knowledge value and priority measure analyst document, information collection and dissemination purpose-related function analyst document; description informed by definitions for 'presence' and 'present', Macquarie Dictionary Online [2012] and Collins Dictionary Online [2012], respectively).

[**Bearing**]: The horizontal angle measured clockwise from a reference direction to a specified direction (Department of Defence, 2012).

[**Information**]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

Electro optical (EO):

The technology associated with those components, devices and systems which are designed to interact between the electromagnetic (optical) and the electric (electronic) state (Department of Defence, 2012). Electro optical (EO) sensors are capable of converting light, or changes in light, into an electronic signal, thus providing a means of detection, target acquisition, and positive identification of entities both in the air and on the ground. It is capable of operating at both day and night, and can provide a real time information feed. It has the capacity to collect information regarding an entity's presence, size, shape, azimuth, and elevation ("Electro-optical sensor," 2012).

- Presence, size, shape, azimuth, and elevation information:

[**Presence**]: The general existence of a specified entity (see knowledge value and priority measure analyst document, information collection and dissemination purpose-related function analyst document; description informed by definitions for 'presence' and 'present' Macquarie Dictionary Online [2012] and Collins Dictionary Online [2012], respectively).

[**Size**]: The dimensions, proportions, or magnitude of anything (Macquarie Dictionary Online, 2012).

[**Shape**]: The external form, contours, or outline of someone or something (Oxford Dictionary Online, 2012).

[Azimuth]: The horizontal angle, measured clockwise by degrees or mils between a reference direction and the line to an observed or designated point (Department of Defence, 2012).

[Elevation]: The vertical distance of a point or level, on, or affixed to, the surface of the earth, measured from mean sea level (Department of Defence, 2012).

[Information]: 1. Unprocessed data of every description which may be used in the production of intelligence (Department of Defence, 2012). 2. Facts, data, or instructions in any medium or form (Department of Defence, 2012).

THREAT WARNING SUBSYSTEM

Physical Object	Object-related Process
Threat warning	Threat warning




Definition of Threat warning:

- **Threat:** An indication of imminent harm, danger, or pain (Collins Dictionary Online, 2012).
- **Warning:** A communication and acknowledgment of dangers implicit in a wide spectrum of activities by potential opponents ranging from routine defence measures to substantial increases in readiness and force preparedness and to acts of terrorism or political, economic, or military provocation (Department of Defence, 2012).

Definition of Threat warning:

- The Collins Dictionary Online (2012) describes the term 'threat' as "an indication of imminent harm, danger, or pain", with 'warning' defined as "a communication and acknowledgment of dangers implicit in a wide spectrum of activities by potential opponents ranging from routine defence measures to substantial increases in readiness and force preparedness and to acts of terrorism or political, economic, or military provocation" (Department of Defence, 2012). As specific to the Air Combat system, the threat warning subsystem affords the object-related process of cautioning against dangers which could negatively impact upon the air combat aircraft or the friendly forces with which it interacts.

THREAT WARNING COMPONENTS

Physical Object	Object-related Process
Missile warning receiver (MWR)  72	Missile threat warning
Laser warning receiver (LWR)  73	Laser threat warning
Radar warning receiver (RWR)  74	Radio frequency (RF) threat warning

⁷² Image source: Mercer Engineering Research Center. (2012). *Advanced Signal Analysis for USAF Missile Warning Receiver Systems: AAR-47 Missile Warning System*. Retrieved from <http://www.merc.mercer.edu/merc/USAF-missile-warning-systems.aspx>.

⁷³ Image source: Thales. (2012). *LWR, MIRAS, ELIX-IR, DIRCM FLASH, CMDS VICON 78: Optronics self-protection/Countermeasures*. Retrieved from http://www.thalesgroup.com/Portfolio/Aerospace/LandJoint_Products_Optronics_self-protection_LWR/.

⁷⁴ Image source: Northrop Grumman. (2012). *AN/APR-39 Radar Warning Receiver (RWR)*. Retrieved from http://www.es.northropgrumman.com/media/photo/ma_air_self-protect.html.

Missile warning receiver (MWR):

A missile warning receiver (MWR) is a type of warning system that detects the thermal signature of potential air-to-air and air-to-surface missile threats to tactical aircraft, and upon detecting threats, seeks to warn the aircrew/command and control ("Missile warning receiver," 2010).

- Missile threat warning:

[Missile]: A self-propelled munition whose trajectory or course is controlled while in flight (Department of Defence, 2012).

[Threat]: An indication of imminent harm, danger, or pain (Collins Dictionary Online, 2012).

[Warning]: A communication and acknowledgment of dangers implicit in a wide spectrum of activities by potential opponents ranging from routine defence measures to substantial increases in readiness and force preparedness and to acts of terrorism or political, economic, or military provocation (Department of Defence, 2012).

Laser warning receiver (LWR):

A laser warning receiver (LWR) is a type of warning system used for passive military defence. It detects laser emissions from laser guidance systems and laser rangefinders, and upon detecting threats, seeks to warn the aircrew/command and control ("Laser warning receiver," 2012).

- Laser threat warning:

[Laser]: A source of high-intensity optical, infrared, or ultraviolet radiation produced as a result of stimulated emission maintained within a solid, liquid, or gaseous medium (Collins Dictionary Online, 2012).

[Threat]: An indication of imminent harm, danger, or pain (Collins Dictionary Online, 2012).

[Warning]: A communication and acknowledgment of dangers implicit in a wide spectrum of activities by potential opponents ranging from routine defence measures to substantial increases in readiness and force preparedness and to acts of terrorism or political, economic, or military provocation (Department of Defence, 2012).

Radar warning receiver (RWR):

A radar warning receiver (RWR) is a type of warning system that detects radio emissions of radar systems. It is used for identifying, avoiding, evading or engaging threats by issuing a warning when a radar signal that might be a threat is detected ("Radar warning receiver," 2012).

- Radio frequency (RF) threat warning:

[RF]: Any of the electromagnetic wave frequencies that lie in the range extending from below 3 KHz to about 300 GHz and that include the frequencies used for communications signals (as for radio and television broadcasting and cell-phone and satellite transmissions) or radar signals (Merriam-Webster Online Dictionary, 2012).

[Threat]: An indication of imminent harm, danger, or pain (Collins Dictionary Online, 2012).

[Warning]: A communication and acknowledgment of dangers implicit in a wide spectrum of activities by potential opponents ranging from routine defence measures to substantial increases in readiness and force preparedness and to acts of terrorism or political, economic, or military provocation (Department of Defence, 2012).

WEAPON SUBSYSTEM

Physical Object	Object-related Process
Weapon	Detonation

Definition of Weapon:

- An offensive or defensive instrument of combat used to destroy, injure, defeat, or threaten an enemy (Department of Defence, 2012).
- Any object which is designed to kill or injure/cause damage (US Department of Defense, 2008).

Definition of Detonation/Detonating:

- The Macquarie Dictionary Online (2012) defines the term 'detonation' as "the act of detonating", with 'detonating' described as being "to cause to explode" and "to explode, especially with great noise, suddenness, or violence" (Macquarie Dictionary Online, 2012). As specific to the Air Combat system, the process that is afforded by the weapon subsystem is that of exploding upon contact with another entity, otherwise labeled as detonation.

WEAPON COMPONENTS

Physical Object	Object-related Process
Air-to-air missile (AAM) 	Air-to-air collision
Air-to-surface missile (ASM) 	Air-to-surface collision
Laser-guided bomb 	Laser-guided homing collision
Unguided bomb 	Ballistic trajectory collision
Cannon 	Close air collision

⁷⁵ Image source: Directory of U.S Military Rockets and Missiles. (2008). *Aim-9*. Retrieved from <http://www.designation-systems.net/dusrm/m-9.html>.

⁷⁶ Image source: AGM-65 Maverick. (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/AGM-65_Maverick.

⁷⁷ Image source: Raytheon. (2012). *F/A-18 Air Dominance*. Retrieved from <http://www.raytheon.com/capabilities/products/apg79aesa/fa18airdom/>.

⁷⁸ Image source: Mark 82 bomb. (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/Mark_82_bomb.

⁷⁹ Image source: M61 Vulcan. (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/M61_Vulcan.

Air-to-air missile (AAM):

An air-to-air missile (AAM) is a missile designed to be launched from an aircraft to strike air targets ("Air-to-air missile," 2012; US Department of Defense, 2008).

- Air-to-air collision:

[Air-to-air]: Operating between or launched from or involving rockets or aircraft in flight ("Air-to-air," 2010).

[Collision]: An instance of one moving object striking violently against another (Oxford Dictionary Online, 2012).

Air-to-surface missile (ASM):

An air-to-surface missile (ASM) is a missile designed to be launched from an aircraft to strike surface targets on land, at sea, or both ("Air-to-surface missile," 2012; US Department of Defense, 2008).

- Air-to-surface collision:

[Air-to-surface]: Operating from or designated to be fired from aircraft at targets on the ground ("Air-to-surface," 2010).

[Collision]: An instance of one moving object striking violently against another (Oxford Dictionary Online, 2012).

Laser-guided bomb:

A laser-guided bomb is described as a bomb which uses a seeker to detect laser energy reflected from a laser marked/designated target (US Department of Defense, 2008).

- Laser-guided homing collision:

[Laser-guided]: A technique of guiding a missile or other projectile to a target by means of a laser beam ("Laser guidance," 2012).

[Homing guidance]: A system by which a missile steers itself towards a target by means of a self-contained mechanism which is activated by some distinguishing characteristics of the target (Department of Defence, 2012).

[Collision]: An instance of one moving object striking violently against another (Oxford Dictionary Online, 2012).

Unguided bomb:

An unguided bomb is described as a bomb which does not contain a guidance system, thereby following a ballistic trajectory, and is designed to be dropped from an aircraft (Department of Defence, 2012; "Unguided bomb," 2012).

- Ballistic trajectory collision:

[Ballistics]: Of or relating to the motion of projectiles proceeding under no power and acted on only by gravitational force, etc. (Macquarie Online Dictionary, 2012).

[Ballistic trajectory]: The trajectory traced after the propulsive force is terminated and the body is acted upon only by gravity and aerodynamic drag (Department of Defence, 2012).

[Collision]: An instance of one moving object striking violently against another (Oxford Dictionary Online, 2012).

Cannon:

A cannon is defined as those weapons which are capable of firing artillery ammunition, encompassing guns and howitzers (Department of Defence, 2012).

- Close air collision:

[Close]: Near in space or time (Collins Online Dictionary, 2012).

[Air]: The invisible gaseous substance surrounding the earth, a mixture mainly of oxygen and nitrogen (Oxford Dictionary Online, 2012), regarded to be the primary medium for the operation of an aircraft (Macquarie Dictionary Online, 2012).

[Collision]: An instance of one moving object striking violently against another (Oxford Dictionary Online, 2012).

COUNTERMEASURE SUBSYSTEM

Physical Object	Object-related Process
Countermeasure	Threat deception




Definition of Countermeasure:

- An opposing measure (Macquarie Dictionary Online, 2012).
- A measure of action taken to counter or offset another one. As a general concept it implies precision, and is any technological or tactical solution or system (often for a military application) designed to prevent an undesirable outcome in the process ("Countermeasure," 2012).

Definition of Threat deception:

- The Collins Dictionary Online (2012) defines a 'threat' to be "an indication of imminent harm, danger, or pain", with 'deception' described as "the act of deceiving or the state of being deceived", and 'deceive' defined as "to mislead by deliberate misrepresentation or lies". As specific to the Air Combat system, the object-related process that is afforded by the countermeasure subsystem is that of deceiving an entity which has the capacity to cause harm, danger, or pain.

COUNTERMEASURE COMPONENTS

Physical Object	Object-related Process
Flare  <small>80</small>	Infra-red jamming
Chaff  <small>81</small>	Electronic jamming
Decoy  <small>82</small>	

Flare:

A pyrotechnic designed to produce a source of light (Department of Defence, 2012). It is employed by aircraft as an aerial infra-red countermeasure to counter infra-red homing air-to-air missiles and surface-to-air missiles by attracting such missiles to the heat signature of the flare rather than the aircraft's engines ("Flare [countermeasure]," 2012).

- Infra-red jamming:

⁸⁰ Image source: Australian Defence Image Library. (2008). *2008 Defence Air Show (F/A-18)*. Retrieved from <http://images.defence.gov.au/fotoweb/>.

⁸¹ Image source: Chaff (countermeasure). (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/Chaff_%28countermeasure%29.

⁸² Image source: AN/ALE-55 Fiber-Optic Towed Decoy. (2012). In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/AN/ALE-55_Fiber-Optic_Towed_Decoy.

[Infra-red]: The part of the electromagnetic spectrum contiguous to the red end of the visible spectrum, comprising radiation of greater wavelength than that of red light (Macquarie Dictionary Online, 2012). Infrared radiation has a wavelength from about 800 nm to 1 mm, and is emitted particularly by heated objects (Oxford Dictionary Online, 2012).

[Jamming]: Deliberate interference, caused by emissions intended to render unintelligible or falsify the whole or part of a wanted signal (Department of Defence, 2012).

Chaff:

Strips of frequency-cut metal foil, wire, or metallised glass fibre used to reflect electromagnetic energy, usually dropped from aircraft or expelled from shells or rockets as a radar countermeasure ("Chaff [countermeasure]," 2012; Department of Defence, 2012).

Decoy:

Decoy countermeasures are manoeuvrable flying objects that are intended to deceive a radar operator into believing that they are actually aircraft. They are especially dangerous because they can clutter a radar with false targets making it easier for an attacker to get within weapons range and neutralise the radar ("Radar jamming and deception," 2012).

- **Electronic jamming:**

[Electronic]: Of, relating to, or concerned with electronics or any devices or systems based on electronics (Macquarie Dictionary Online, 2012).

[Jamming]: Deliberate interference, caused by emissions intended to render unintelligible or falsify the whole or part of a wanted signal (Department of Defence, 2012).

SURVIVAL ASSISTANCE SUBSYSTEM

Physical Object	Object-related Process
Survival assistance	Life support



Definition of Survival assistance:

- *Survival*: A person or thing that survives (Collins Dictionary Online, 2012).
- *Assistance*: The act of assisting; help; aid (Macquarie Dictionary Online, 2012).

Definition of Life support:

- The Oxford Dictionary Online (2012) specifies 'life' as "the condition that distinguishes animals [used in the broadest sense of the term] and plants from inorganic matter, including the capacity for growth, reproduction, functional activity, and continual change preceding death", whereas the Macquarie Dictionary Online (2012) defines 'life' to be "a state or condition of existence as a human being". For the current analysis, aspects of both definitions will be utilised to represent life within an air combat context. Specifically, life is an attribute of entities, in particular human beings, which have the capacity for growth, activity etc., and which are exclusively situated within the Air Combat aerial system. 'Support', as defined by the Macquarie Dictionary Online (2012), is the ability "to sustain (a person, the mind, spirits, courage, etc.) under trial or affliction". As afforded by the survival assistance subsystem, the concept of life support collectively refers to the capacity to ensure and sustain the life of the air combat aircrew.

SURVIVAL ASSISTANCE COMPONENTS

Physical Object	Object-related Process
Survival stores  83	Crew sustainment
Ejection system  84	Ejection

Survival stores:

A package of basic tools and supplies prepared in advance as an aid to survival in an emergency ("Survival kit," 2012). These basic tools/supplies can fall into four general categories: 1) First aid, 2) Signalling, 3) Shelter, and 4) Water/food. The content of these stores depend on the environmental conditions of the operation i.e., desert areas, tropical areas. Collectively, they all contribute to the sustainment of aircrew life.

⁸³ An example of an aviation survival store/kit. Image source: BCB Survival USA. (n.d.). Retrieved from <http://www.bcb Survival USA.com/xcart/catalog/Aircrew-Survival-Pack-MK4-p-16140.html>.

⁸⁴ An image of a JSF ejection seat (US16E). Image source: Defense File. (2012). *Martin-Baker US16E ejection seat flies in F-35 Lightning II*. Retrieved from http://www.defensefile.com/Customisation/News/Military_Aviation/Safety_Escape_and_Recovery_Systems/Martin-Baker_US16E_ejection_seat_flies_in_F-35_Lightning_II.asp.

- Crew sustainment:

[Crew]: The persons operating an aircraft in flight (Collins Dictionary Online, 2012).

[Sustainment]: To maintain or continue for a period of time (Collins Dictionary Online, 2012).

Ejection system:

An ejection system is described as the escape from an aircraft by means of an independently propelled seat or capsule (Department of Defence, 2012). Effectively, the seat propels out from the aircraft by an explosive charge or rocket motor, carrying the specified aircrew (i.e., pilot/air combat officer) with it ("Ejection seat," 2012), thus affording ejection as an object-related process.

- Ejection:

[Ejection]: The act of ejecting (Macquarie Dictionary Online, 2012), with 'ejecting' described as to drive or force out; expel, as from a place or position (Macquarie Dictionary Online, 2012).

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19. ABSTRACT The Royal Australian Air Force’s Air Combat Capability is currently undergoing a significant restructure as new, advanced platforms are introduced to the fleet. To avoid a loss of capability in the air domain, the Royal Australian Air Force must determine how best to employ its current and future fighter jets to meet operational goals. To support this objective, this report presents a comprehensive work domain analysis—or structural description—of Australia’s Air Combat Capability, defined across multiple levels of abstraction and decomposition, and independent of specific platforms. This analysis has already demonstrated its usefulness in contributing to the development of an Australian air power doctrine and strategy narrative, represented in the next edition of the Royal Australian Air Force’s Air Power Manual (AAP 1000-D). Future applications of this model could contribute to capability requirements definition; air combat force structure development and organisational redesign; air combat specific crewing concepts, training programs, and Concept of Operations; and the continued development of military doctrine and strategy.							